THE ROLE OF PUBLIC TRANSPORTATION IN ACCESS TO CARE FOR OLDER ADULTS IN THE UNITED STATES

by
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Abstract

Among older adults in the United States, transportation is the third most commonly cited barrier to care. Existing research on transportation as a barrier to accessing health services is limited to rural areas and access to private vehicles, yet transportation is as much a barrier to care for older adults living in urban areas. This research addresses three questions on the topic of aged Medicare beneficiaries' use of public transportation and access to health services. First, whether there is a valid measure of access to public transport. Second, whether access to public transport is associated with its use to travel to a usual source of care. Finally, whether access to public transport is associated with more appropriate use of outpatient health services. We found that two existing measures of public transport accessibility, the Transport Connectivity Index (TCI) and the Transit Access Shed (TAS) are valid measures of public transport accessibility, both for Census block groups and ZIP Code tabulation areas (ZCTAs). Overall, approximately 5% of older adult Medicare beneficiaries take public transportation to get to their usual source of care. Additionally, individuals living in areas with better public transportation are more likely to take public transportation to get to their usual source of care, independent of the other barriers to care or health status. However, I did not find a relationship between access to public transportation and appropriate use of outpatient services. Beneficiaries living in areas with better public transportation were equally likely to have at least one primary care visit during the year, and were hospitalized for ambulatory care sensitive conditions at the same rate as beneficiaries living in areas with worse public transportation. Future research should

work to understand how beneficiaries without private vehicles are getting to health services and to evaluate other transportation alternatives.

Advisor: Darrell J. Gaskin, PhD

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As far as I can tell, every doctoral thesis is a product of both pride and frustration, and mine is no exception. I have truly enjoyed the work I have done on access to care for older adults, and am incredibly pleased with the final product. There are so many people who have contributed to this process and product, and I would like to acknowledge some of them here.

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Contents

Tables

Figures

Chapter 1. Introduction

In the United States, residents face multiple barriers to receiving outpatient services including preventive services, primary care, and maintenance of chronic conditions. Among older adults in the United States, cost is the greatest barrier to care, followed by appointment availability, transportation or distance, and clinic office hours.[1] Similarly, a recent study found that although financial barriers were the single most common reason for unmet healthcare needs or delayed care in the United States, they did not make up the majority of reasons. Even among respondents who experienced financial barriers, two-thirds had additional non-financial barriers. Respondents with chronic illnesses, who are most likely to need regular outpatient care, were more likely to face non-financial barriers than their healthier counterparts.[2]

This research focus on the third most commonly cited barrier to care, transportation, for the older adult population. A recent study estimated that 3.6 million Americans annually do not obtain needed medical care due to a lack of transportation to appointments.[3] In a consensus statement on non-emergency medical transportation (NEMT) among older adults, transportation is known to be “a critical component of health care access” (p. 828).[4] Although 90% of adults 65 and older drive, this proportion declines with age and is related to health status, meaning that those who are most in need of transportation to health services are often unable to drive themselves.[4]

Most of the existing research on transportation as a barrier to accessing health services is limited to rural areas and access to private vehicles, yet transportation is as much a barrier to care for older adults living in urban areas.[5,6] Previous research has found that both distance to providers and available modes of transportation play an important role in accessing health services in rural areas.[7] In urban areas, public transportation may provide an alternative mode of transport, but then restricts access to areas not served by the transport system.[8]

In terms of access to health services, public transportation operates in a different way than private vehicles, and research on transportation via private vehicle may not be applicable to individuals who rely on public transport. Specifically, public transportation schedules may affect arrival times and increase travel time as compared to private vehicles, but public transport can usually get patients to clinics eventually. In contrast, lack of access to private vehicles can prevent a patient from getting to a healthcare facility at all.[9] In a review of research in geographic information systems (GIS) and access to care, Higgs notes that "more research is needed to investigate the potential role of geography on utilization for a wider range of health measures in a range of settings and for differing modes of transportation (for example, for areas/communities with households with low levels of access to private transportation)" (p. 91).[10]

As compared to the general population, older adults face somewhat different barriers to care than the general population: they generally have health insurance but may have decreased access to private transportation, social networks, and mobility.[9] Although the majority of older adults live in suburbs, 21% lived in city centers in 2002,[11] and it is estimated that 15.5 million lived in urban areas with poor transit access[*] in 2015.[12] As the US population ages, the number and proportion of older adults that will rely on public

[*] The definition of poor transit access is dependent on the size of the urban area, but is less than two bus, rail, or ferry routes within ½ mile of a residence for all cities besides New York City.

transportation is expected to grow substantially and with them the number of people who rely on public transportation to access health services.[12]

It is important to understand how the public transportation infrastructure affects these individuals' use of health services to inform both transportation and health policy. This research addresses three questions on the topic of aged Medicare beneficiaries' use of public transportation and access to health services. First, I examine whether there is a valid measure of access to public transport. Second, whether access to public transport is associated with its use to travel to a usual source of care. Finally, I address whether access to public transport is associated with more appropriate use of outpatient health services.

Conceptual Model

Multiple factors contribute to an individual's ability to access health services, often referred to as barriers to care. Although this research is particularly focused on transportation barriers to care, access to care is jointly affected by all barriers an individual encounters, and for this reason it is important to understand the scope of barriers to accessing health services.

Access to care can be conceptualized in a number of ways,[13] but one of the most common descriptions of the construct of access to health services and the dimensions contained in this construct was developed by Penchansky and Thomas. Using data from a health plan satisfaction survey, the authors describe five dimensions of the concept of access to health services: availability, accessibility, accommodation, affordability, and acceptability. All of these measures are based on relationships between the supply and demand of health services. Availability deals with the number and type of services, accessibility is the location of services, accommodation is the organization of services, affordability is the price of services, and acceptability is the attitudes of both providers and patients towards giving and receiving care. These dimensions were used to develop the survey and then validated through survey responses and loadings of a factor analysis.[14]

Additionally, other studies have shown that the dimensions interact with each other. For example, in rural regions where geography impacts accessibility, service accommodation is often poor as well and patients cannot access appropriate providers. Among groups with greater affordability barriers, there is often a decreased availability of services. Thus, research can deal with a single dimension, the interaction of dimensions, or the full construct of access to health services. To best understand the full construct of access to health services, however, it is important to incorporate multiple dimensions and to understand their interactions.[13]

In addition to conceptualizing the construct of access to care, more recent models include temporal relationships between barriers to care and use of health services. One such model is the Institute of Medicine's (IOM) model for monitoring access. In this model, barriers to care are categorized as structural, financial, or personal.[15] Comparing these barriers to Penchansky and Thomas' five dimensions of access to care, financial barriers are equivalent to the dimension of affordability and personal barriers are the same dimension as acceptability. Three dimensions, accessibility, accommodation, and availability, together comprise structural barriers. These barriers influence the use of health services, which in turn influence health outcomes. The relationship between health service use and health outcomes is mediated by treatment appropriateness and efficacy, provider quality, and patient adherence.[15] In the IOM framework, transportation is specifically listed as a structural barrier, and since this is the focus of my question I have separated it from other structural barriers.

In addition to transportation, structural barriers include availability of services and organizational barriers. In terms of financial barriers, the IOM specifically mentions insurance, out-of-pocket payments, and public support for health services. Finally, the IOM considers cultural and language barriers, acceptability and attitudes toward receiving care, and socioeconomic status to be personal barriers. All of these affect use of health services, which in my case is restricted to outpatient services. The IOM model also includes mediators and health outcomes, which I have not included in my model as I am most interested in service utilization, which comes before health outcomes (Figure 1.1). In addition to the IOM framework, I have added the need for health services, which precedes any barriers to care. Although this is not part of the IOM's model, it is included in another well-established model of access to care developed by Anderson and Aday.[16] Finally, I have included mediators between barriers to care and health services use. In the case of transportation barriers, these include other available transportation, as older adults are often driven to appointments if they cannot drive themselves,[7] and an individual's mobility, as limited mobility has been shown to be associated with lower health service utilization.[17]

The IOM model is commonly used to describe barriers to care and especially transportation barriers; validating the model for my population of interest. Among low SES adults, financial, personal, and structural barriers were commonly reported to contribute to unmet healthcare needs.[18] For dual eligible Medicare and Medicaid beneficiaries, race, health status, functional status, and functional distress were all associated with barriers to care; most commonly organizational barriers but also many geographic barriers.[19] Among low-income older adults in Florida, structural and personal barriers together made receiving needed care difficult, as those without private transportation or social support were also fearful of using other methods (such as public transportation) to get to appointments.[9] Looking specifically at public transportation as a barrier to care, one study had a population where 36% of respondents walked or used public transportation to get to an ambulatory care clinic in Atlanta. Those who walked or used public transport were less likely to have a usual source of care and more likely to wait two or more days to get needed care. These measures were statistically significant in models adjusted for demographics and multiple barriers to care.[20]

Literature Review

Transportation barriers to access to health services

To measure transportation barriers, it is necessary to first define them. In the literature, those with transportation barriers to access to care can be described as transportation disadvantaged. Although there is no single definition of this term, the consensus statement on non-emergency medical transportation (NEMT) for older adults defines transportation disadvantaged as those who do not have access to and/or cannot operate a private vehicle and thus must rely on alternate means of transportation.[4] This definition is problematic for research on public transportation because it would mean that most people who take public transport to receive medical care would be considered transportation disadvantaged, despite the fact that some may choose to take public transport over other available modes of transportation. The definition is based on the fact that the majority of Americans take private vehicles to medical appointments, but does not account for the fact that private vehicles are not always the preferred mode of transport. A more reasonable definition for this research comes from another study that defined adequate transportation to healthcare as the ability to reach a healthcare facility within 30 minutes on public transport or 15 minutes of walking.[21] Similarly, the Graduate Medical Education National Advisory Committee for primary care determined that patients should not be expected to travel more than 30 minutes to reach their provider.[22] Using these more expansive definitions, some individuals who do not drive to receive health services may still have adequate transportation to health providers. Although there is no single definition of transportation barriers to access to care, it is clear that without appropriate means and reasonable travel time, transportation is a barrier to care.

In addition to defining transportation barriers, when thinking about access to health services, it is important to distinguish between potential and realized access. Potential access is the ability of individuals to use health services, while realized access (sometimes referred to as revealed access) is when these individuals actually take advantage of the available services.[23] Few studies have specifically addressed the association between potential and realized access, but one study of pharmacy services focused specifically on geographic accessibility. The researchers found that there was an association between potential and realized access, however, measures of potential access were approximately half of the distance that patients actually traveled for pharmacy services.[24] It is unknown whether the use of outpatient services follows a similar pattern.

A recent review of transportation barriers in access to care found 61 published studies on the topic.[25] Overall, the author finds that there is a large range in the proportion facing transportation barriers that is dependent on population characteristics; depending on the population studied, transportation is a barrier for between 3% and 67% of the sample. In terms of the effects of transportation barriers, the author concludes, based on the published literature, that transportation barriers affect access to both providers and pharmacies. Transportation barriers disproportionally affect racial and ethnic minorities (even after controlling for differences in SES) and vulnerable populations including children, the elderly, and veterans. For other commonly studied differences such as rural or urban residents and distance to care, the link between transportation barriers and access to care is not conclusive among the studies reviewed.

Public transportation and access to care

Only a few studies have looked at public transportation and realized access to care, and depending on the population studied and information available on public transport use, they have found differing associations. Among patients in an immigrant community who arrived at an outpatient clinic in suburban New York, 24% of those interviewed reported previously missing or rescheduling an appointment due to transportation problems. This proportion was even higher among the 15% of patients who had arrived at the clinic by bus.[26] In a survey of North Carolina's Appalachian counties, respondents who reported using public transportation were more likely to need health services than the overall group of respondents: they were older and had poorer health. In this case, those respondents who used public transportation had more chronic care visits but not more regular care visits than the entire study population.[27] In a qualitative study of older adults in central and south Florida, respondents reported difficulty using public transit due to difficulty getting to stops, increased travel time, and discomfort while traveling on the transportation system.[28]

In contrast, studies that have used ecological data have not been able to find a relationship between public transportation and health services use. In a national analysis of receipt of preventive services among female respondents to the Behavioral Risk Factor Surveillance System (BRFSS), ecological measures of commuting time and use of public transportation were not associated with the receipt of a pap smear or mammogram.[29] Additionally, a study examining the effect of a bus driver strike on the proportion of missed appointments at a Minneapolis teaching hospital's outpatient department found that the no-show rate was similar before and during the strike.[30]

Despite the demonstrated need for services, across the United States, most older adults prefer private vehicles to public transportation, as walking and boarding vehicles can be difficult.[11] In one survey of older adults in Vermont, those who did not have access to a private vehicle were more likely to report having delayed medical appointments.[31] Another survey of adults in rural and small urban areas in the U.S. Great Plains states looked at the association between transportation, travel distance, and health service utilization. In these areas, the majority of respondents used private vehicles to get to physicians' offices, but 5% used public transport, 3% used volunteer driver services, and 2% used services provided by human service agencies. Use of these alternatives to private vehicles increased the probability of having difficulties traveling to care, but this relationship was not statistically significant. Additionally, 35% of respondents who did not have access to public transit indicated that they would use public transit to travel to care if it were available.[32] In a qualitative study of senior villages in Washington, DC, the most common service that village members requested was transportation to medical appointments.[33]

Other research has used GIS analysis to quantify potential access to care. Based on a GIS analysis of public transport options in three low-income counties in California, only one third of residents are within a 30 minute travel time via public transit to a hospital, and only 26% of residents are within a 30 minute travel time to a community health clinic.[21]

Research on public transportation's association with access to health services outside the United States may provide some insight into these relationships in the United States. However, public transportation plays very different roles around the world and findings may not be generalizable to other regions. An analysis of local health service accessibility in rural areas of the United Kingdom used patient records to map the distance from patient's homes to their clinic. In this study, the authors found that 82% of people had good bus accessibility (defined as four or more daily routes spread throughout the day), but 13% had no bus accessibility. Additionally, areas without public transportation were predominantly lower SES than those with good accessibility.[34] Using the same data, the researchers were able to study the effect of distance in a patient's choice to go to a clinic further away. Again, the availability of public transportation showed no association with a patient choosing to travel further to receive care. However, patients were more likely to go to the closest clinic when it was within walking distance.[35] Additionally, a survey of adults in Montreal Island, Quebec, Canada, found that seniors in the suburbs were more likely to have access to a car, but also had to travel further to receive health services, than those living in the city.[36]

To address some of the gaps in the existing research, this research examines measures of potential access (the availability of public transportation) and then uses them to determine realized access (the use of public transportation and outpatient services).

Measures

This research addresses older adult Medicare beneficiaries' access to public transportation and use of health services. In order to evaluate these relationships, I will use measures that cover the following topics:

- Public transport quality
- Medicare beneficiaries' use of public transport
- Medicare beneficiaries' appropriate use of health services

Population of interest

All of the analyses use the same population of interest: older adults in urban areas of the United States. For area level measures such as transportation quality, this would include the quality of transportation available in urban areas.

Public transport quality

Because all of my analyses focus on potential access to public transportation, all three use measures of public transport quality. This data is available from the nonprofit group The Center for Neighborhood Technology (CNT) and consists of two proprietary measures: the transit access shed (TAS) and the transit connectivity index (TCI), discussed in detail in the validation study. Briefly, the TAS is a measure of public transportation quality that determines the area that can be reached via public transportation from a given location in 30 minutes. The TCI is a measure of transportation access that measures the number of transportation options and their frequency. These measures are available for all cities in the US with populations of at least 50,000 people.[37]

The TAS and TCI are provided at the Census block group level. However, the analyses of use of public transportation and health services among older adults uses Medicare data (discussed in more detail below) to identify beneficiaries locations. In this data source, the ZIP code is the most granular geographic identifier available. In order to determine the quality of public transportation at a beneficiary's residence, the transport measures have been aggregated to the ZCTA using a weighted average based on the number of households in each block group.

Medicare beneficiaries' use of public transport

Individuals' use of public transit comes from the 2011 Medicare Current Beneficiary Survey (MCBS). The MCBS is an annual health survey administered by the Centers for Medicare & Medicaid Services (CMS). The MCBS uses a three year rotating panel design of approximately 15,000 beneficiaries in total to provide both cross sectional and longitudinal information on access to and satisfaction with care, health status, and health care costs, use, and payment.[38] The MCBS includes questions on many barriers to care, including the focus of my analysis, a beneficiary's mode of transport to their usual source of care.

Medicare beneficiaries' appropriate use of health services

In these analyses, I use two indicators of appropriate use of health services: (1) having at least one primary care visit during the year, and (2) not having potentially preventable hospitalizations.

The importance of primary care visits is well known, but has recently been recognized by providing a free annual wellness visit for all Medicare beneficiaries.[39] However, less than half of older adults are up to date in terms of receiving core clinical preventive services.[40]

Additionally, access to outpatient services can be operationalized by defining certain conditions as "ambulatory care sensitive," focusing on outpatient services that keep patients healthy.[41] This designation was developed in response to the need to measure quality of care throughout the health system, and is measured by emergency room (ER) visits and hospitalizations for the ambulatory care sensitive conditions.[41] As opposed to quality measures obtained from patients at outpatient clinics, measuring hospital visits for ambulatory care sensitive conditions allows researchers to understand access among patients that do not interact with the outpatient system at all. For these individuals, barriers to accessing health services do more than make access difficult, they prevent access to outpatient services altogether.

Information about beneficiaries' use of health services relies on Medicare fee-for-service claims. For this analysis, I used Medicare data from a simple random sample of 5% of Medicare beneficiaries (100% of claims for 5% of beneficiaries) from CMS from 2011, including both inpatient and carrier claims.

Potentially preventable hospitalizations are identified from the Medicare inpatient claims file. A hospitalization is considered potentially preventable if it was for a condition identified by the Agency for Healthcare Research and Quality's (AHRQ) prevention quality indicators. These are 14 indicators[*] that can be used with hospital inpatient discharge data (such as the inpatient claims data) to identify ambulatory care sensitive conditions based on ICD-9 codes.[41]

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[*] The prevention quality indicators are diabetes short-term complications, perforated appendix, diabetes long-term complications, chronic obstructive pulmonary disease, hypertension, congestive heart failure, low birth weight, dehydration, bacterial pneumonia, urinary tract infection, angina without procedure, uncontrolled diabetes, adult asthma, and lower-extremity amputation among patients with diabetes

Primary care use is based on both carrier and outpatient claims data. Outpatient claims are submitted by outpatient hospital departments and the carrier claims are submitted by freestanding clinics. Claims were considered to be for a primary care visit if the provider was eligible for CMS' Primary Care Incentive Payment (PCIP) program. The PCIP was established under the Affordable Care Act and increases payments for primary care services provided by qualifying primary care providers beginning in 2011. CMS identifies primary care services provided in the outpatient setting with CPT codes 99201-99215. To be considered a primary care provider (PCP), at least 60% of a provider's Medicare claims must be for these primary care services.[42]

References

1. Okoro CA, Strine TW, Young SL, Balluz LS, Mokdad AH. Access to health care among older adults and receipt of preventive services. Results from the Behavioral Risk Factor Surveillance System, 2002. Preventive Medicine 2005;40:337-43.
2. Kullgren JT, McLaughlin CG, Mitra N, Armstrong K. Nonfinancial Barriers and Access to Care for U.S. Adults. Health Serv Res 2012;47:462-85.
3. Wallace R, Hughes-Cromwick P, Mull H, Khasnabis S. Access to health care and nonemergency medical transportation - Two missing links. Management and Public Policy 2005. Washington: Transportation Research Board National Research Council; 2005:76-84.
4. Flaherty JH, Stalvey B, Rubenstein L. A consensus statement on nonemergent medical transportation services for older persons. Journals of Gerontology Series A-Biological Sciences and Medical Sciences 2003;58:826-31.
5. Blazer DG, Landerman LR, Fillenbaum G, Horner R. Health-Services Access and Use Among Older Adults In North-Carolina - Urban vs Rural Residents. American Journal of Public Health 1995;85:1384-90.
6. McDonald JT, Conde H. Does Geography Matter? The Health Service Use and Unmet Health Care Needs of Older Canadians. Canadian Journal on Aging-Revue Canadienne Du Vieillissement 2010;29:23-37.
7. Arcury TA, Gesler WM, Preisser JS, Sherman J, Spencer J, Perin J. The effects of geography and spatial behavior on health care utilization among the residents of a rural region. Health Serv Res 2005;40:135-55.

8. Glaeser EL, Kahn ME, Rappaport J. Why do the poor live in cities? The role of public transportation. Journal of Urban Economics 2008;63:1-24.
9. Rittner B, Kirk AB. Health-Care and Public Transportation Use by Poor and Frail Elderly People. Soc Work 1995;40:365-73.
10. Higgs G. The role of GIS for health utilization studies: literature review. Health Services and Outcomes Research Methodology 2009;9:84-99.
11. Rosenbloom S. The mobility needs of older Americans: implications for transportation reauthorization. Washington, DC: Brookings Institution; 2005. Report No.: 0815748272.
12. DeGood K. Aging in Place, Stuck without Options: Fixing the Mobility Crisis Threatening the Baby Boom Generation: Transportation for America; 2011.
13. Ansari Z. A review of literature on access to primary health care. Australian Journal of Primary Health 2007;13:80-95.
14. Penchansky R, Thomas JW. The concept of access: definition and relationship to consumer satisfaction. Medical Care 1981;19:127-40.
15. Millman M. Access to health care in America: National Academies Press; 1993.
16. Andersen RM. Revisiting the behavioral model and access to medical care: does it matter? Journal of health and social behavior 1995:1-10.
17. Satariano WA, Guralnik JM, Jackson RJ, Marottoli RA, Phelan EA, Prohaska TR. Mobility and Aging: New Directions for Public Health Action. American Journal of Public Health 2012;102:1508-15.

18. Malmgren JA, Martin ML, Nicola RM. Health care access of poverty-level older adults in subsidized public housing. Public Health Reports 1996;111:260-3.
19. Niefeld MR, Kasper JD. Access to ambulatory medical and long-term care services among elderly Medicare and Medicaid beneficiaries: organizational, financial, and geographic barriers. Medical Care Research and Review 2005;62:300-19.
20. Rask KJ, Williams MV, Parker RM, McNagny SE. Obstacles Predicting Lack of a Regular Provider and Delays in Seeking Care for Patients at an Urban Public Hospital. Journal of the American Medical Association 1994;271:1931-3.
21. Hobson J, Quiroz-Martinez J, Yee C. Roadblocks to health: Transportation barriers to healthy communities. Transportation and Land Use Coalition 2002.
22. Continelli T, McGinnis S, Holmes T. The effect of local primary care physician supply on the utilization of preventive health services in the United States. Health & Place 2010;16:942-51.
23. Probst JC, Laditka SB, Wang J-Y, Johnson AO. Effects of residence and race on burden of travel for care: cross sectional analysis of the 2001 US National Household Travel Survey. BMC Health Services Research 2007;7.
24. Lin S-J, Crawford SY, Warren Salmon J. Potential access and revealed access to pain management medications. Social Science & Medicine 2005;60:1881-91.
25. Syed ST, Gerber BS, Sharp LK. Traveling Towards Disease: Transportation Barriers to Health Care Access. Journal of community health 2013:1-18.

26. Silver D, Blustein J, Weitzman BC. Transportation to Clinic: Findings from a Pilot Clinic-Based Survey of Low-Income Suburbanites. Journal of Immigrant and Minority Health 2012;14:350-5.
27. Arcury TA, Preisser JS, Gesler WM, Powers JM. Access to transportation and health care utilization in a rural region. Journal of Rural Health 2005;21:31-8.
28. Ruggiano N, Shtompel N, Whiteman K, Sias K. Influences of Transportation on Health Decision-Making and Self-Management Behaviors among Older Adults with Chronic Conditions. Behavioral Medicine 2015:00-.
29. Coughlin SS, King J. Breast and cervical cancer screening among women in metropolitan areas of the United States by county-level commuting time to work and use of public transportation, 2004 and 2006. BMC Public Health 2010;10.
30. Pheley AM. Mass transit strike effects on access to medical care. Journal of Health Care for the Poor and Underserved 1999;10:389-96.
31. Hadley Strout E, Fox L, Castro A, et al. Access to transportation for Chittenden County Vermont older adults. Aging Clinical and Experimental Research 2015:1-6.
32. Mattson J. Transportation, Distance, and Health Care Utilization for Older Adults in Rural and Small Urban Areas. Transportation Research Record 2011:192-9.
33. Guengerich T. Neighbors Helping Neighbors: Qualitative Study of Villages Operating in the District of Columbia: AARP; 2009.
34. Lovett A, Haynes R, Sunnenberg G, Gale S. Car travel time and accessibility by bus to general practitioner services: a study using patient registers and GIS. Social Science & Medicine 2002;55:97-111.

35. Haynes R, Lovett A, Sunnenberg G. Potential accessibility, travel time, and consumer choice: geographical variations in general medical practice registrations in Eastern England. Environment and Planning A 2003;35:1733-50.

36. Paez A, Mercado RG, Farber S, Morency C, Roorda M. Accessibility to health care facilities in Montreal Island: an application of relative accessibility indicators from the perspective of senior and non-senior residents. International journal of health geographics 2010;9.

37. Haas P, Morse S, Becker S, Young L, Esling P. The influence of spatial and household characteristics on household transportation costs. Research in Transportation Business & Management 2013.

38. Medicare Current Beneficiary Survey. Centers for Medicare and Medicaid Sevices, 2013. (Accessed August 1, 2013, at http://www.cms.gov/Research-Statistics-Data-and-Systems/Research/MCBS/index.html.)

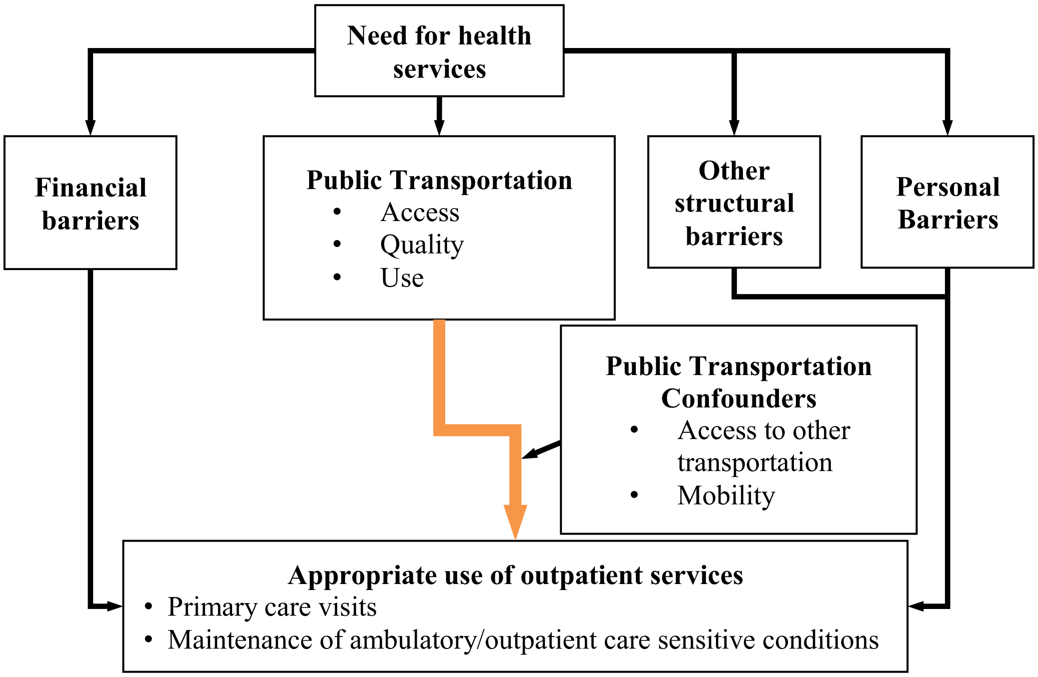
39. Preventive visit & yearly wellness exams. Centers for Medicare & Medicaid Services. (Accessed March 18, 2016, at https://www.medicare.gov/coverage/preventive-visit-and-yearly-wellness-exams.html.)

40. Benson W, Aldrich N. CDC Focuses on Need for Older Adults to Receive Clinical Preventive Services: Centers for Disease Control and Prevention; 2012.

41. Guide to prevention quality indicators: hospital admission for ambulatory care sensitive conditions: Agency for Healthcare Research and Quality; 2001.

42. Centers for Medicare and Medicaid Services. Summary Information Regarding Medicare's Primary Care Incentive Payment Program (PCIP) April 30, 2014.

Figure 1.1 Conceptual model of the role of public transportation in access to care, modified from the Institute of Medicine's (IOM) model for monitoring access to health services



Chapter 2. Measuring Access to Public Transportation: A Validation of the Transit Connectivity Index and Transit Access Shed

Introduction

As health in all policies focus on understanding patients' built environment, it is important to accurately characterize environmental factors that may affect health. These include home and work environments, as well as travel. One such factor that is difficult to measure is the mode of travel individuals have access to and use, including public transportation. Although public transportation is not is not traditionally considered when categorizing environments as healthy or not, recent research has shown that the quality and use of public transport is associated with health behaviors and outcomes. Given these findings, recent reports have noted the importance of transport planning to achieve public health goals.[1]

The quality and use of public transportation is associated with other health behaviors and healthy environments. First, use of public transportation is associated with other active transport methods, including walking and biking, and with increased physical activity while using the public transport system.[2-5] Additionally, use of public transportation is associated with reduced carbon emissions, particularly in urban environments where driving conditions create disproportionate emissions for the small number of vehicle miles traveled in private vehicles.[6,7]

Public transportation use and quality is associated with other built environment characteristics including street connectivity, land-use,[8] traffic safety, and crime.[3] Thus, to accurately characterize the urban built environment, is important to include measures of public transportation. For studies where public transportation is not the focus, well-validated, publicly available measures of public transportation that could be easily included along with other aspects of the built environment could enhance research.

In addition to the associations between public transport and other built environment characteristics, public transport has the potential to impact access to destinations, including health services. Transportation is known to be a barrier to accessing health services, and models of access to care, including that developed by the Institute of Medicine (IOM), incorporate transportation in their understanding of use of health services.[9] Despite this knowledge, there is little research on the role that public transportation plays in enabling access to health services. A recent health impact assessment of the effects of reducing bus service in the Boston area included access to health care as a potential outcome and assumed that in areas losing bus service, households without privately owned vehicles would no longer have access to healthcare. In this assessment the authors also acknowledge that many factors beyond car ownership and public transportation affect transportation access to health services.[10] In part, this gap may be due to the difficulty in measuring the quality of public transport.

Despite these advantages, we are not aware of any measure of transport quality that has been validated across the country, making measuring the quality of public transport both difficult and burdensome. Many transit agencies provide stop and timetable information in a publicly available, standardized format, General Transit Feed Specification (GTFS).[11] Yet these raw datasets are not easily manipulated and do not directly address the quality of public transportation to or from a given location.[12] Having validated, nationwide transit measures would allow researchers to evaluate health outcomes by the quality of public transit, or to control for the quality of public transit when evaluating other outcomes. This analysis evaluates the construct validity of two transit measures that were developed together: the Transit Connectivity Index (TCI) and the Transit Access Shed (TAS), for the accessibility of public transit from a given location. Additionally, we evaluate the validity at two different geographic levels, the Census block group and ZCTA, as most geographic location variables are either Census measures or addresses including ZIP codes.

Public transportation access measures

The quality of public transportation is determined by a number of factors including access, reliability, and satisfaction. Access typically refers to the physical location of transit stops and the connectivity between them. Accessibility may focus on frequency of service, travel time, and network coverage. Reliability measures whether the transit system operates in line with published schedules.[13] Satisfaction looks at customers perceptions of public transport, which is generally determined by the relationship between perceived and expected service.[14] Satisfaction may measure perceived access or reliability, as well as fare price, perceived safety, cleanliness and comfort.[15] Research has shown that these factors are not always related, particularly comparing service to reliability. For example, customers who stand for the entire ride perceive longer travel time and when they are seated unrelated to the actual travel time.[15]

There are two significant aspects of the public transport system typically included in access measures. First, there is accessibility of origin stops, typically measured by the distance to a stop and the frequency of service at that stop. The second important indicator of access to public transportation is destinations that can be reached via the transport system. Existing transportation measures include information about origins and/or destinations and may also include connectivity information about how efficiently the system allows individuals to get from origins to destinations.[16,17]

Information about the origin is generally obtained from GTFS data and includes buffer zones around origin stops. These buffers may be circles around the stop measuring Euclidean distance or more sophisticated measures of walking paths to the origin stop.[16] Destinations may be defined as transit stops or locations of interest. Locations of interest are often workplaces,[18] but could be health service destinations, such as hospitals or clinics. Beyond the simple ability to reach a certain destination, measures often impose time limits, such as 30 minutes, to show the destinations are reachable under realistic conditions.[18]

Methods

In this analysis, we are evaluating two measures of public transportation accessibility, comprised of three indices. These measures were developed by the Center for Neighborhood Technology (CNT), a nonprofit organization focused on urban environments in the United States.[19] CNT developed these transportation measures as a part of the Housing + Transportation Index, an effort to accurately determine the cost of living in an area by including both housing and travel costs. The measures are based on CNT's propriety All Transit database, which incorporates additional transit agencies in addition to the publicly available GTFS data.[20] The measures were first developed in 2008. We are evaluating updated data based on information collected about public transit agencies between 2010 and 2012.

The two measures of public transportation are the Transit Connectivity Index (TCI) and the Transit Access Shed (TAS). Both were developed for Census block groups in cities greater than 50,000 people. The methodology for the transportation measures is described in detail by Haas et al.[20] Briefly, the TCI measures the number of transit stops available within or near a block group. Stops are weighted by their distance from the block group and the frequency of service. The TAS consists of two separate indices both measuring where an individual can travel within 30 minutes from an origin. One index, the TAS-distance, measures the distance that can be reached within 30 minutes, while the other, the TAS-destinations, measures the number of transit stops that can be reached within 30 minutes. Both allow for transfers within the time frame and are weighted by the frequency of service at the origin. The range of the TAS measures is relatively large, with the TAS-distance ranging from 0 to 133,512 and the TAS-destinations with a range of 0 to 3,026. To facilitate comparisons across the three measures, we divided TAS-distance by 1,000 and the TAS-destinations by 10 for this analysis.

Some validation of the measures has already been conducted, evaluating their correlation with measures of private vehicle availability and proportion of workers commuting via public transit, based on block group estimates from the American

Community Survey (ACS).[20] This is an important first validation of the measures, but may not be sufficient to rely on them for future analyses. In a review of the entire Housing + Transportation Index, the transport measures were noted to be useful, but the validity of the transit measures alone was not evaluated.[21]

Our validation expands CNT's first steps in a number of ways. First, we replicate their validation with the updated transit measures. We also evaluate the validity of the transit measures for individual behavior, rather than area measures. Separately, we examine the validity at the county and city area, as the accessibility of public transit should vary significantly both within and between cities.

Beyond our evaluation of CNT's block group measures, we have generated and evaluated TCI and TAS measures at the ZIP code tabulation area (ZCTA) level to understand whether these measures are also valid for representing access to public transport. Although the measures were developed for Census block groups, researchers often work with data including addresses rather than Census geographies. In this case, the smallest area unit is the zip code, which is not a Census geography. However, the Census Bureau has aggregated Census blocks into ZCTAs to facilitate using Census data with ZIP code identifiers. For these analyses, we aggregated block groups to ZCTAs using a population weighted average of all block groups in the ZCTA. Note that because ZCTAs aggregate blocks rather than block groups, some block groups are included in more than one ZCTA.

Other data sources

The data used to validate the TCI and TAS were taken from a number of sources and manipulated as necessary to be comparable to these measures.

City level information was based on the Core Based Statistical Areas (CBSA) developed by the US Office of Management and Budget. CBSAs map urban counties into metropolitan and metropolitan areas. We used the 2013 update of CBSAs based on Census 2010 data.[22]

Much of the area level data was obtained through the MABLE/Geocorr Geographic Correspondence Engine maintained by the Missouri Census Data Center. This includes Census block group and ZCTA population, area, housing units, and population centroids. We also obtained CBSA total population and population centroids from this source. These were used to generate population and housing density as the number per square mile, and the straight line distance to the city population center. The Engine creates allocation files from one geographic unit to another, so this was also the source of the crosswalk used to create ZCTA measures from the block group measures provided by CNT, including the mapping and weighting from block groups to ZCTAs.

Additional area level attributes came directly from the Census Bureau. We used 2007-2011 ACS five year estimates for the proportion of households with at least one vehicle and the proportion of adults that take public transportation to work.[23] For these same measures at the block group level, we used 2006-2010 ACS five year estimates.[24]

Measures of urbanicity are based on the US Department of Agriculture's Rural-Urban Continuum Codes for counties, last updated in 2013. This includes 3 categories of metropolitan areas and 6 categories of nonmetropolitan areas.[25]

Individual and household measures come from the 2009 National Household Transportation Survey (NHTS). The NHTS is a representative survey of 150,000 households and includes household information and responses from each member of the household, including a travel diary for a randomly selected day.[26] From the survey, we used the number of vehicles in the household, the mode of transportation adults took to work, and whether respondents had taken public transport on their recorded travel day. For individual level measures, we accounted for individuals within the household having the same location by averaging values across the household, and then weighting analyses by the number of individuals per household. We used households' block groups and ZIP codes to identify their location. ZIP codes were crosswalked to ZCTAs using a publically available crosswalk file.[27]

Some information on use of public transportation came from the 2010 National Transit Database maintained by the Federal Transit Administration.[28] This contains the number of unlinked transit trips and fare revenue by provider. We matched the provider's primary urban area to CBSAs and the generated per capita measures based on the CBSA population obtained from MABLE/Geocorr.

Finally, we compared the TCI and TAS to other public transportation accessibility measures. One measure determined the number of destinations that are reachable by workers during rush hour as a proxy for access to jobs. Access was determined at the block level and then aggregated to CBSAs.[29] We compared the average TAS and TCI values for the five cities with the best access (New York, NY; San Francisco, CA; Los Angeles, CA; Washington, DC; Chicago, IL) and the five with the worst (Orlando, FL; Nashville, TN; Virginia Beach, VA; Riverside, CA; Birmingham, AL).[18] The other model we used to evaluate the TAS and TCI determined the number of workers with access to public transportation within a city based on the population living in a Census block group with a transit stop within three quarters of a mile of the block group's population centroid. We again compared the five cities with the highest proportion of workers with access to public transit (Honolulu, HI; Los Angeles, CA; San Jose, CA; El Paso, TX; San Francisco, CA) to those with the lowest proportion (Augusta, GA; Jackson, MS; Knoxville, TN; Greenville, SC; Chattanooga, TN).[30] Although neither of these measures are validated, we expect that if all of these measures are measuring public transport accessibility to some degree, they will be correlated.

Validation

We evaluated the construct validity of the TCI and TAS as measures of access to public transportation. Construct validity measures the relationship between the measures of interest and other measures hypothesized to be related to them. Since each of the measures is slightly different, we evaluated the TCI and both TAS measures for each construct. Additionally, we evaluated the block group and ZCTA measures for each construct.

Our evaluation framework is shown in Table 2.1. We considered three concepts related to public transportation accessibility (shown in the first column): neighborhood structural characteristics, transit use, and other measures of transit accessibility. Each of these concepts had related constructs (column 2). For example, the concept of structural characteristics included six constructs: urbanicity, population and housing density, city size, distance from the city center, and private vehicle availability. We develop hypotheses on both the direction and strength of the relationship of each construct with the measures of transportation accessibility. For example, we hypothesized that areas with more private vehicle availability would have less accessible public transit, and that the strength of this relationship would be weaker than the relationship between population density and access to public transportation. Each construct was evaluated using one or more specific measures. For example, private vehicle availability was evaluated with three measures: whether household had at least one vehicle, the number of vehicles per adult in the household, and the proportion of households in the area with at least one vehicle.

We used two validation methods: correlation and known groups. Pearson correlation coefficients and their statistical significance where used to evaluate the TCI and TAS against other continuous measures, such as population density or distance to the city center. When evaluated against categorical measures, such as cities with good or poor transit, we used known group validation to compare the mean of the TCI and TAS across groups. Known group validation uses groups that are expected to have different levels of the idea being validated (in this case access to public transportation) to determine whether values of the measure differ across groups. In our case, we compared the mean of the TCI and TAS indices across the groups. For measures with only two groups (such as whether or not households had a car), we used a t-test to determine whether the values were significantly different between groups; for measures with more than two groups (such as the RUCCs) we used an F-test.

Results

In total, we validated 184,156 block groups and 16,651 ZCTAs across 735 cities. Descriptive statistics for the TCI and TAS are shown in Table 2.2. All of the indices are right skewed: for block groups, the TCI has a mean of 4.8 (SD: 9.9) and a maximum of 100, while the TAS-distance has a mean of 12.6 (SD: 14.5) with a maximum of 134 and the TAS-destinations has a mean of 16.2 (SD: 23.0) and a maximum of 303. The distributions are similar for ZCTAs, although the values are generally lower. Sample sizes and distributions of the other measures are shown in Table 2.3. Not all measures were available for every location. For example, annual trips were available for 284 of the 735 total cities in our sample.

The validity of the TCI and TAS with structural constructs is shown in Table 2.4. Generally, both the TCI and TAS at the block group and ZCTA level show strong construct validity against all of the structural measures. For the RUCC as a measure of urbanicity, more urban counties have higher values of the TCI and both TAS measures than more rural counties. Population density, housing density, and city size are all highly positively correlated with the TAS and TCI measures. Although the distance from center city is negatively correlated as predicted, the Pearson correlation coefficient is smaller than hypothesized. In terms of private vehicle availability, households with a vehicle are more likely to be located in areas with low values of the TCI and TAS than households without a vehicle. The TCI and TAS are also highly negatively correlated with the number of vehicles per adult in the household and the number of households in an area with one or more private vehicles. The correlation coefficients are quite similar for block groups and ZCTAs; the average values for urban areas and households with private vehicles are lower for ZCTAs, as would be expected by the distribution of the measures.

Transit use constructs are shown in Table 2.5. All of the measures of use of public transport are positive and statistically significant, as hypothesized. The proportion of workers in the area taking public transit to work is the most highly correlated measure with both the TCI and TAS, but all of the correlations are fairly large and statistically significant. The same is true for the annual revenue from transit fares per capita. Again, the correlation coefficients are similar for both block groups ZCTAs.

Finally, the comparisons to other measures of transit accessibility are shown in Table 2.6. We find that for both comparison measures, cities considered to have more accessible public transportation have significantly higher values of the TCI and TAS then cities with poor public transport. As with structural and transit use concepts, these measures perform similarly well at the block group and ZCTA level.

Given that all constructs behaved in the direction that was hypothesized and most had the strength that we hypothesized, we feel that the TCI and TAS are valid measures of access to public transportation at both the Census block group and ZCTA level.

Discussion

We found that the TCI and TAS are valid measures of public transport accessibility. The measures were valid for the structural and public transport use constructs that we measured, and performed well compared to other measures of access to public transportation. Additionally, they performed well against multiple data sources. Not only were we able to validate the measures that CNT originally developed, but we also aggregated these block group measures to the ZCTA level, and found that the measures were equally valid for the ZCTAs.

Although we found these measures to be valid measures of public transport accessibility based on our analysis, there are some limitations to our analysis and to the future use of these measures. These measures are currently available for cities with populations of 50,000 or greater in the United States. Thus, even if the measures were generated for smaller cities, we have not evaluated whether they accurately measure access to public transportation in nonurban areas. Additionally, although the basic methods used to develop the TCI and TAS have been published, the actual measures are proprietary, and the current publications do not contain the details that would allow other researchers to replicate the measures. For this reason, we assumed that the computation of the measures is consistent with their published description, but we have no way to verify that.

Finally, we were only able to use construct validation for analysis, and other validation techniques could strengthen or weaken our findings. In particular, it is ideal to validate a measure compared to a gold standard. However, there is no gold standard measure of public transport accessibility, so we are unable to do this type of validation. In fact, we are not aware that any measure of access to public transport has been empirically validated, yet there are a number of other proposed public transportation measures. Future research could validate these measures and compare them to the TAS and TCI to understand the differences between the measures.

The TCI and TAS measure public transportation accessibility, which is only one part of the quality of a transit system. Each transit system could be separately evaluated for reliability and satisfaction, and more accessible systems may not necessarily perform better on these other quality measures. Thus, access is only one factor in an individual's decision to use public transportation. Although we believe that more accessible transportation is more likely to be used than less accessible transportation, other quality factors may significantly impact public transit use.

Despite these limitations, we believe that the validity observed in this analysis justifies using the TAS and TCI in future research. These measures could be used either in research focusing on public transportation, or as a measure of the built environment in research with a different focus. In our future research, we will use these measures to determine the availability of public transportation at a given location to better understand the role that transportation plays in access to health services.

References

1. Litman T. Evaluating public transportation health benefits: Victoria Transport Policy Institute Victoria, British Columbia, Canada; 2015 February 27.
2. Bopp M, Gayah VV, Campbell ME. Examining the Link Between Public Transit Use and Active Commuting. International Journal of Environmental Research and Public Health 2015;12:4256-74.
3. Zwald ML, Hipp JA, Corseuil MW, Dodson EA. Correlates of Walking for Transportation and Use of Public Transportation Among Adults in St Louis, Missouri, 2012. Preventing Chronic Disease 2014;11:E112.
4. Rissel C, Curac N, Greenaway M, Bauman A. Physical Activity Associated with Public Transport Use-A Review and Modelling of Potential Benefits. International Journal of Environmental Research and Public Health 2012;9:2454-78.
5. Saelens BE, Vernez Moudon A, Kang B, Hurvitz PM, Zhou C. Relation Between Higher Physical Activity and Public Transit Use. American Journal of Public Health 2014;104:854-9.
6. Woodcock J, Edwards P, Tonne C, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. The Lancet;374:1930-43.
7. Kwan SC, Hashim JH. A review on co-benefits of mass public transportation in climate change mitigation. Sustainable Cities and Society 2016;22:11-8.
8. Turrell G, Haynes M, Wilson L-A, Giles-Corti B. Can the built environment reduce health inequalities? A study of neighbourhood socioeconomic disadvantage and walking for transport. Health & Place 2013;19:89-98.

9. Millman M. Access to health care in America: National Academies Press; 1993.
10. James P, Ito K, Buonocore JJ, Levy JI, Arcaya MC. A Health Impact Assessment of proposed public transportation service cuts and fare increases in Boston, Massachusetts (USA). International Journal of Environmental Research and Public Health 2014;11:8010-24.
11. A Brief History of GTFS. Institute of Transportation Studies Berkley, 2014. (Accessed March 21, 2016, at http://library.its.berkeley.edu/node/265.)
12. Pioneering Open Data Standards: The GTFS Story. 2013. (Accessed March 21, 2016, at http://beyondtransparency.org/chapters/part-2/pioneering-open-data-standards-the-gtfs-story/.)
13. Barabino B, Deiana E, Tilocca P. Urban transport management and customer perceived quality: a case study in the metropolitan area of Cagliari, Italy. Theoretical and Empirical Researches in Urban Management 2011;6:19.
14. Randheer K, AL-Motawa AA. Measuring commuters' perception on service quality using SERVQUAL in public transportation. International Journal of Marketing Studies 2011;3:p21.
15. Friman M, Fellesson M. Service supply and customer satisfaction in public transportation: The quality paradox. Journal of Public Transportation 2009;12:57-69.
16. Mamun SA, Lownes NE, Osleeb JP, Bertolaccini K. A method to define public transit opportunity space. Journal of Transport Geography 2013;28:144-54.

17. Mishra S, Welch TF, Jha MK. Performance indicators for public transit connectivity in multi-modal transportation networks. Transportation Research Part A: Policy and Practice 2012;46:1066-85.

18. Owen A, Levinson D. Access Across America: Transit 2014. Minneapolis, MN: University of Minnesota; 2014 September. Report No.: 14-11.

19. Vision + Mission. Center for Neighborhood Techonology, 2015. (Accessed March 21, 2016, at http://www.cnt.org/vision-and-mission.)

20. Haas P, Morse S, Becker S, Young L, Esling P. The influence of spatial and household characteristics on household transportation costs. Research in Transportation Business & Management 2013.

21. Econsult Corporation. Review of the Center for Neighborhood Technology's Housing and Transportation Affordability Index. Philadelphia, PA2012 February.

22. Current Lists of Metropolitan and Micropolitan Statistical Areas and Delineations. United States Census Bureau. (Accessed March 21, 2016, at http://www.census.gov/population/metro/data/metrodef.html.)

23. American FactFinder. United States Census Bureau, 2013. (Accessed 8/15/2013, 2013, at http://factfinder2.census.gov.)

24. Index of ACS 2010 5 year summary files. United States Census Bureau, 2012. (Accessed March 21, 2016, at http://www2.census.gov/acs2010_5yr/summaryfile/2006-2010_ACSSF_All_In_2_Giant_Files(Experienced-Users-Only)/.)

25. Rural-Urban Continuum Codes. United States Department of Agriculture, 2013. (Accessed March 21, 2016, at http://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx.)

26. 2009 National Household Travel Survey. U.S. Department of Transportation, Federal Highway Administration; 2009.

27. ZIP Code to ZCTA Crosswalk. American Academy of Family Physicians, 2015. at http://www.udsmapper.org/zcta-crosswalk.cfm.)

28. National Transit Database. 2012 ed: Federal Transit Administration; 2010.

29. Owen A, Levinson D. Access Across America: Transit 2014 Methodology. Minneapolis, MN: University of Minnesota; 2014 September. Report No.: CTS 14-12.

30. Adie Tomer EK, Robert Puentes, and Alan Berube. Missed Opportunity: Transit and Jobs in Metropolitan America. Washington, DC: The Brookings Institution; 2011 May.

Table 2.1 Framework for validating measures of public transportation availability

Concept	Construct	Hypothesis		Measure	
		Direction	Strength	Variable	Test
Structural	Urbanicity	+	Medium	USDA RUCC	Known groups
	Population Density	+	Medium	Population density per square mile	Correlation
	Housing density	+	Medium	Housing density per square mile	Correlation
	City size	+	Strong	CBSA population	Correlation
	Distance from central city	-	Strong	Distance from central city	Correlation
	Private vehicle availability	-	Medium	Households with at least 1 vehicle	Known groups
				# of vehicles per adult	Correlation
				% of HH with any vehicles	Known groups
Transit use	Use of public transit	+	Strong	Use public transit on travel day	Correlation
				Transportation to work	Correlation
				% taking public transit to work	Correlation
				Annual # of transit trips per capita	Correlation
	Transit revenue	+	Strong	Annual per capita fare revenue	Correlation
Transit accessibility	Other measures of access to public transportation	+	Strong	Cities with best and worst access to jobs via public transit	Known groups
				% working age population with access to public transit by city	Known groups

USDA: United States Department of Agriculture
RUCC: Rural urban continuum code

Table 2.2 Descriptive statististics of public transportation availability measures

	Census Block Group				ZIP Code Tabulation Area (ZCTA)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Transit Connectivity Index (TCI)	4.8	9.9	0	100	2.1	6.3	0	66
Transit Access Shed (TAS)								
Distance	12.6	14.5	0	134	6.9	12.2	0	114
Destinations	16.2	23.0	0	303	8.1	16.0	0	171

Table 2.3 Descriptive statistics of validation constructs and measures

Concept	Construct	Measure	Source	Level	n	Value (SD)	
Structural	Urbanicity	USDA RUCC	USDA	County	1536	1. Metro (>1 million people)	27.2%
						2. Metro (250,000-1 million)	22.5%
						3. Metro (<250,000)	14.2%
						4. Nonmetro, adjacent to a metro area (20,000+)	11.0%
						5. Nonmetro, not adjacent to a metro area (20,000+)	4.1%
						6. Nonmetro, adjacent to a metro area (2,500-19,999)	10.0%
						7. Nonmetro, not adjacent to a metro area (2,500-19,999)	7.0%
	Population Density	Population density per square mile	MABEL	BG	184,156	7064 (15,910)	
				ZCTA	16,649	2088 (6476)	
	Housing	Housing density per square	MABEL	BG	184,156	3070 (7750)	

Concept	Construct	Measure	Source	Level	n	Value (SD)
	density	mile		ZCTA	16,651	919 (3217)
	City size	CBSA population	MABEL	CBSA	735	368,800 (1,367,641)
	Distance from central city	Distance from central city (miles)	MABEL	BG	184,156	18.6 (62)
				ZCTA	16,649	51.9 (154.8)
	Private vehicle availability	Households with at least 1 vehicle	NHTS	Household	81,174	94.5%
		# of vehicles per adult	NHTS	Household	81,174	1.08 (0.56)
		% of households with any vehicles	Census	BG	184,156	90.2% (0.15)
				ZCTA	16,444	96.8% (0.07)
Transit use	Use of public transit	Use public transit on travel day	NHTS	Individual	93,268	2.4%
		Transportation to work	NHTS	Individual	142,356	3.3%
		% taking public transit to work	Census	BG	184,085	6.1% (0.13)
				ZCTA	16,487	3.1% (0.08)
		Annual # of transit trips per capita	NTD	CBSA	284	19.5 (116.9)
	Transit revenue	Annual per capita fare revenue	NTD	CBSA	228	$11.78 (24.80)
Transit accessibility	Other measures of	Cities with best and worst access to jobs via public	Owen and Levinson,	CBSA	10	Best 5 and worst 5 by public transit access

Concept	Construct	Measure	Source	Level	n	Value (SD)
	access to public transportation	transit	2014			
		% working age population with access to public transit by city	Tomer et al., 2011	CBSA	10	5 withand 5 with lowest proportion

USDA: United States Department of Agriculture
RUCC: Rural urban continuum code
NHTS: National household travel survey
NTD: National transit database
BG: Census block group
ZCTA: ZIP Code tabulation area
CBSA: Census based statistical area

Table 2.4 Validity results of structural constructs for measures of public transportation availability

Construct	Validation Measure	Public transportation availability measure					
		Block Groups			ZCTAs		
		TCI	TAS: Distance	TAS: Destinations	TCI	TAS: Distance	TAS: Destinations
Urbanicity	USDA RUCC						
	1. Most urban	7.24	16.79	22.57	4.16	12.01	14.52
	2	1.50	9.20	9.03	0.84	5.62	5.49
	3	0.87	4.20	5.21	0.23	1.43	1.95
	4	0.03	0.24	0.45	0.01	0.19	0.24
	5	0.14	0.65	1.72	0.04	0.42	0.76
	6	0.00	0.02	0.03	0.00	0.03	0.05
	7. Most rural	0.01	0.03	0.16	0.00	0.00	0.02
Population Density	Population density	0.77	0.32	0.64	0.81	0.45	0.70
Housing density	Housing density	0.72	0.29	0.61	0.77	0.42	0.67
City size	CBSA population	0.50	0.30	0.48	0.27	0.17	0.26
Distance from central city	Distance from central city	-0.07	-0.10	-0.08	-0.09	-0.14	-0.13
Private vehicle availability	Vehicles per household						
	None	11.36	17.34	30.05	10.94	16.63	29.04
	1 or more	2.41	9.77	11.17	2.56	10.12	11.65
	# of vehicles per adult	-0.21	-0.16	-0.20	-0.21	-0.15	-0.21
	% of HH with any vehicles	-0.70	-0.37	-0.60	-0.75	-0.42	-0.64

TCI: transit connectivity index
TAS: transit access shed
USDA RUCC: United States Department of Agriculture's rule urban continuum codes
ZCTAs: ZIP Code tabulation areas
All comparisons are statistically significant at $p<0.001$

Table 2.5 Validity results of transit use constructs for measures of public transportation availability

Construct	Validation Measure	Public transportation availability measure					
		Block Groups			ZCTAs		
		TCI	TAS: Distance	TAS: Destinations	TCI	TAS: Distance	TAS: Destinations
Use of public transit	Use public transit on travel day	0.39	0.16	0.32	0.39	0.17	0.34
	Transportation to work	0.41	0.16	0.34	0.41	0.16	0.36
	% taking public transit to work	0.83	0.41	0.72	0.86	0.51	0.78
	# of transit trips per year per resident	0.50	0.19	0.45	0.38	0.19	0.37
Transit revenue	Fare revenue per capita per year	0.53	0.16	0.47	0.36	0.14	0.34

TCI: transit connectivity index
TAS: transit access shed
ZCTAs: ZIP Code tabulation areas
All comparisons are statistically significant at $p<0.001$

Table 2.6 Validity results of transit accessibility constructs for measures of public transportation availability

Construct	Validation Measure	Public transportation availability measure					
		Block Groups			ZCTAs		
		TCI	TAS: Distance	TAS: Destinations	TCI	TAS: Distance	TAS: Destinations
Other measures of access to public transportation	Access to jobs via public transit						
	Cities with the best access	14.0	21.8	36.0	8.3	16.9	24.2
	Cities with the worst access	1.4	10.6	10.7	0.8	7.7	6.9
	Proportion of the working age population with access to public transit						
	Cities with the highest proportion	7.8	25.8	27.1	6.9	24.6	24.7
	Cities with the lowest proportion	0.7	3.7	4.4	0.9	3.2	4.4

TCI: transit connectivity index
TAS: transit access shed
ZCTAs: ZIP Code tabulation areas
All comparisons are statistically significant at $p<0.001$

Chapter 3. Access to and Use of Public Transportation Among Medicare Beneficiaries

Introduction

Among older adults, lack of transportation to medical services is one of the most common barriers to care.[1] Although transportation is recognized as a barrier for many groups,[2] it operates somewhat differently for older adults than the general population: they may have decreased access to private transportation, social networks, and mobility.[3] Although 90% of adults 65 and older drive, this proportion declines with age and is related to health status, meaning that those who are most in need of health services are often unable to drive themselves and may turn to other modes to access care.[4] In urban areas, public transportation is increasingly providing an alternative form of transportation for non-drivers. Between 2001 and 2009, the share of trips for older adults taken by public transportation increased by 40%, and non-drivers relied on public transport for nearly a quarter of all trips.[5] Despite the recent growth, older adults took only 1.5% of all trips by public transport in 2009,[5] which may be partially due to the fact that nearly a third of older adults were predicted to live in areas with poor transit access in 2015.[6]

In order to rely on public transportation to access health services, older adults need to have the option available and then choose to take it. These two factors can be distinguished as potential and realized access to public transport: potential access is the ability of individuals to use a service, while realized access (sometimes referred to as revealed access) is when these individuals actually take advantage of available services.[7]

Although the availability or use of public transportation has been studied, we are not aware of any research that specifically addresses the association between potential and realized access to public transportation for health services. Surveys of specific patient populations have found varying relationships between realized access to public transportation and the use of outpatient services, from patients being more likely to miss or reschedule appointments[8] to having more chronic care appointments.[9] In contrast, studies that have looked only at potential access to public transport have not been able to find a relationship between public transportation and health service use.[10,11]

In order to untangle the differences between access to public transport and health service use, it is important to first understand the relationship between potential and realized access to public transportation itself in the context of health services: if public transportation is available, do individuals use it to travel to health services? How do other barriers or enablers to accessing health services affect the relationship between public transportation and access to care? In this analysis, we address the relationship between potential and realized access to public transportation as well as individual characteristics that influence the use of public transport when it is available.

Conceptual framework

In terms of understanding the role of transportation in access to care, the Institute of Medicine's (IOM) model is most appropriate and has been used to understand the relationship between transportation and access to health services in previous research.[3,12-14] This model describes barriers to accessing health care, which affect use of health services. Once an individual chooses to use health services, their health outcomes may still be mediated by factors including appropriateness of care, efficacy of treatment, quality of providers, and patient adherence to provider recommendations.[15] For this research, we are focused on the barriers to accessing health services, which, in the IOM framework, fall into the categories of structural, financial, and personal barriers. In the model, transportation is considered a structural barrier, along with the availability of services and the organization of health services. All of the barriers together affect an individual's use of health services, and they may interact to further encourage or discourage use.

Methods

Data

To evaluate the relationship between potential and realized access to public transport, we used two separate data sources. For potential access, two measures have been developed by the Center for Neighborhood Technology (CNT) to measure public transport availability from a given location: the transit access shed (TAS) and the transit connectivity index (TCI). The TAS represents the area that can be reached via public transportation in 30 minutes including 2 indices: the maximum distance and the possible locations reached within that time period. The TCI is a measure of transportation availability based on the number of transportation options and their frequency. Both measures are based in 2010-2012 transit data and are available for all cities in the U.S. with at least 50,000 residents.[16] These two measures produce 3 indices (the TCI, TAS-distance, and TAS-destinations). Although each is based on measurable factors, all are scaled by the frequency of service and thus are not interpretable in specific units. The TCI is specifically scaled from 0-100, while the range of the TAS measures are larger. For all of these indices, greater values indicate better access to public transportation.

To measure realized access to public transportation among older adults, we used self-reported data from the 2011 Medicare Current Beneficiary Survey (MCBS) conducted by the Centers for Medicare and Medicaid Services (CMS). The MCBS asks all respondents to identify a usual source of care (USC) and then to select their typical mode of transportation to get there. Thus, our sample was restricted to respondents who identified a usual source of care and a mode of transport. We categorized modes of transport into 5 categories: driving, being driven, taking public transport/walking, or some other mode of transportation (including ambulance, taxi, doctor coming to the beneficiary's home, and other unspecified modes). Although the focus of this research is the use of public transportation, walking was also included in this category as another form of active transport. However, the majority of this group took public transportation. Additionally, we excluded beneficiaries not living in urban areas, defined as those addresses not in a Core Based Statistical Area (CBSA).[*17]

Individual characteristics reported in the MCBS that could influence the relationship between potential and realized access to public transportation were considered in analysis. These include demographics (age, race, gender, education, poverty level), health status and mobility (overall health status, number of comorbid

[*] CBSAs were developed by the US Office of Management and Budget. CBSAs map urban counties into metropolitan and metropolitan areas.

conditions, difficulty walking), barriers to care (household composition, English language proficiency) and location of USC (doctor's office/group practice, doctor's clinic, hospital outpatient department/veteran's administration facility, or another type).

Geographic Measures

The MCBS includes limited information on beneficiaries' location, with the most detailed level being their ZIP code. In contrast, the TCI and TAS are measured at the Census block group level. Thus, in order to match transportation measures to beneficiaries, we needed a shared geography between Census block groups and ZIP codes, the zip code tabulation area (ZCTA). Because ZIP codes are used by the postal system and are not a Census geography, there is no direct relationship between ZIP codes and any Census geography. However, the Census Bureau in 2000 specifically established ZCTAs to address this issue.[18] ZCTAs are aggregated from Census blocks and approximate the area covered by ZIP codes. We converted beneficiaries' 5 digit ZIP codes to ZCTAs using a publically available crosswalk.[19] We also aggregated the TCI and both TAS indices to the ZCTA level using a weighted average of each index based on the proportion of the total population from each block group in each ZCTA. Finally, we divided values of the TAS-destinations by 10 and the TAS-distance by 1,000 to make the ranges of the 3 indices and subsequent comparisons of regression results similar.

Analysis

We first looked at the raw relationship between potential and realized access to transportation. We divided each measure of potential access (TCI, TAS-distance, TAS-destinations) into 3 categories: zero, bottom 20% of the range of values, and top 80% of the range. We then looked at the distribution of potential and realized access within select cities.

To evaluate the association between beneficiaries' potential and realized access to public transportation, , we used multilevel multinomial logit models for the relative risk of taking public transportation/walking as compared to driving themselves. We chose to use a multinomial model because the dependent variable, transportation to a USC, has more than 2 categories. In this case, we had three nested levels: individuals and two area levels. The beneficiary and their characteristics was the first individual level, the beneficiary's ZCTA and its characteristics was the second level, and the city where the ZCTA was located was the third level. All models included both beneficiary and ZCTA fixed effects as covariates by controlling for beneficiary characteristics and including ZCTA level measures of the TCI and TAS. City information was included as random effects, with city specific intercepts based on the core based statistical area (CBSA) of a beneficiary's residence.

We evaluated this relationship in a base model, in models stratified by other barriers to care and health status measures, and finally in a model incorporating all variables. The base model included the independent variables of interest (the TCI and TAS) and controlled for beneficiaries' demographics to understand the influence of public transport without accounting for other barriers to care. We then ran the same base model for groups stratified by 6 characteristics: location of USC, household composition, language survey was completed in, overall health status, difficulty walking, and dual eligibility. These models allowed us to see whether the relationship between the availability and use of public transportation differed across groups. Finally, we evaluated the relationship controlling for all available covariates.

(CBSA)). All analyses were performed using Stata 12 and the gllamm software.[20]

Results

The analysis sample includes 7,595 MCBS respondents, of which 375 use public transportation to get to their usual source of care (Table 3.1). As compared to other groups, beneficiaries who took public transportation were less likely to be white, were less educated, and were more likely to be dually eligible for Medicare and Medicaid. They were also more likely to face additional barriers to care, including completing the survey in a language other than English or having difficulty walking.

The sample included 1,332 ZCTAs in 135 CBSAs. Across ZCTAs, the mean TCI was 4.9 (standard deviation: 9.8), the TAS-distance had a mean of 13.2 (SD: 13.2) and the mean TAS-destinations was 16.9 (SD: 21.7). Table 3.2 shows the distribution of ZCTAs and sample respondents for the three measures of potential access. Depending on the measure, 15-20% of both ZCTAs and respondents are in areas with values of zero on the potential access measures, meaning that they have no public transport in the area. An additional 50-80% of ZCTAs and respondents are in areas with potential access in the bottom fifth of the indices, meaning that they have very limited potential access to public transport. Very few areas fall in the top fifth of the range for each measure. However, the proportion of respondents using public transport (realized access) increases as potential access increases.

Figure 3.1 shows two areas, New York City and central Florida, and the measures of potential and realized access to public transportation across ZCTAs in each location. Both potential and realized access levels and distributions differ across locations. In central Florida, there is little variation in potential access to public transport—most ZCTAs have either zero values or fall in the bottom fifth of the range for all three measures. Accordingly, less than 20% of respondents use public transport in nearly all ZCTAs in this location. In contrast, there is significant variation in the New York City area, with the most potential access in the center and decreasing access further away. Realized access to public transport follows the same pattern.

The results from the base model, including only demographics, are shown in Table 3. For all models, the reference group is respondents who drove themselves to their USC, compared to those that were driven, took public transportation or walked, and those using other forms of transportation. Only results from the comparison between driving and taking public transit/walking are shown. In the base model, beneficiaries in areas with better potential access to public transport are significantly more likely to use public transit than to drive themselves. This is particularly true in areas with greater availability of public transit (measured by the TCI). Those beneficiaries with that can access more locations via public transit (measured by the TAS-destinations) are also more likely to be driven than to drive themselves, but potential access to public transit that allows riders to travel further (TAS-distance) does not appear to increase the likelihood of being driven as opposed to driving themselves.

Models stratified by other barriers to care are shown in Table 3.4. For those barriers that interact with public transport, the role of public transport quality should differ between stratified models, while those that are independent will have the same relationship between the potential and realized access for both models. Across the barriers, the strongest enablers for the TCI are weaker for the TAS, although the association between potential and realized access to public transportation is relatively consistent despite other barriers. For example, availability of public transport (the TCI) is a greater enabler to use of public transport for beneficiaries with mobility limitations who have difficulty walking ¼ mile, but being able to access more locations via public transit (the TAS-destinations) is a significant enabler for those beneficiaries with greater mobility. The type of a beneficiary's USC is the only measure that seems to make a significant difference in the relationship. Beneficiaries going to a doctor's office or clinic are likely to benefit from greater public transport availability (the TCI), but not from being able to travel more places (the TAS measures).

The final model in Table 3.3 includes demographics, health status, and other barriers to care. In this case, the TCI and TAS-destinations continue to be positively associated with realized access to public transportation. Greater availability of public transportation, as measured by the TCI, is associated with a 6% greater relative risk of taking public transport rather than driving. Greater availability measured by the TCI-destinations is associated with a 2% increase in the relative risk, while there is not a statistically significant association with the TAS-distance. Thus, the relationship between potential and realized access to public transport acts independently of the other barriers to care and health status measures. In this model, the other barriers to care continue to be significant and separate predictors of use of public transport as well.

Discussion

Overall, we did find a relationship between measures of potential access to public transportation and realized access in the context of health services. Generally, individuals are more likely to use public transit if it is more available. However, consistent with previous research, we found that few MCBS respondents chose public transportation at all; most drove themselves to their USC. Even in areas with the best public transport realized access could be relatively low, when measured by the TCI areas in at the top of the range had realized access as high as 80%, but the TAS using distance had realized access of only about 40% in the highest areas.

After accounting for beneficiary characteristics, we still found a significant relationship between potential and realized access to public transportation. Although this relationship is strong, there are still few older adults taking public transportation at all, and those that are using it seem to be concentrated in the few areas with the best potential access. For these reasons, it is not surprising that studies measuring realized access to public transportation have been able to show an association with health service use, but those using potential access have had more difficulty. In order to see the latter association, researchers need sufficient power to detect differences in service use even after the attenuation between potential and realized access to public transport, which would generally require a large sample.

Our study was able to find an association between potential and realized access to public transportation for health services, but there are some limitations to the findings. We are able to examine relative differences in potential access to public transport as measured by public transport availability, but the nature of the measures we used does not allow us to categorize the overall quality of the transport system. Our sample was also restricted to individuals who could identify a usual source of care, and these beneficiaries may be different than those who do not have a usual source of care, including their use of public transportation. We also do not know the specifics of respondents' origin and destination of their usual source of care, but have assumed that public transportation accessibility in general is also applicable to transportation to a usual source of care. Our finding that there is an association between potential and realized access supports this assumption. We chose to include walking with taking public transportation since they are both modes of active transport, but if walkers are different in some way than those taking public transportation, this may affect our findings. Finally, we used potential access measures at the ZCTA level due to the availability of information about MCBS respondents. However, ZCTAs are of varying sizes, and some are very large. We assumed that potential access was uniform across the ZCTA, although that may not be the case in practice.

Establishing the relationship between potential and realized access to public transportation for older adults travel to health services is a starting point to address the relationship between public transportation and the appropriate use of health services in this population. Future research will need to address this question.

References

1. Okoro CA, Strine TW, Young SL, Balluz LS, Mokdad AH. Access to health care among older adults and receipt of preventive services. Results from the Behavioral Risk Factor Surveillance System, 2002. Preventive Medicine 2005;40:337-43.
2. Syed ST, Gerber BS, Sharp LK. Traveling Towards Disease: Transportation Barriers to Health Care Access. Journal of community health 2013:1-18.
3. Rittner B, Kirk AB. Health-Care and Public Transportation Use by Poor and Frail Elderly People. Soc Work 1995;40:365-73.
4. Flaherty JH, Stalvey B, Rubenstein L. A consensus statement on nonemergent medical transportation services for older persons. Journals of Gerontology Series A-Biological Sciences and Medical Sciences 2003;58:826-31.
5. Lynott J, Figueiredo C. How the Travel Patterns of Older Adults Are Changing: Highlights from the 2009 National Household Travel Survey 2011.
6. DeGood K. Aging in Place, Stuck without Options: Fixing the Mobility Crisis Threatening the Baby Boom Generation: Transportation for America; 2011.
7. Probst JC, Laditka SB, Wang J-Y, Johnson AO. Effects of residence and race on burden of travel for care: cross sectional analysis of the 2001 US National Household Travel Survey. BMC Health Services Research 2007;7.
8. Silver D, Blustein J, Weitzman BC. Transportation to Clinic: Findings from a Pilot Clinic-Based Survey of Low-Income Suburbanites. Journal of Immigrant and Minority Health 2012;14:350-5.

9. Arcury TA, Preisser JS, Gesler WM, Powers JM. Access to transportation and health care utilization in a rural region. Journal of Rural Health 2005;21:31-8.

10. Coughlin SS, King J. Breast and cervical cancer screening among women in metropolitan areas of the United States by county-level commuting time to work and use of public transportation, 2004 and 2006. BMC Public Health 2010;10.

11. Pheley AM. Mass transit strike effects on access to medical care. Journal of Health Care for the Poor and Underserved 1999;10:389-96.

12. Malmgren JA, Martin ML, Nicola RM. Health care access of poverty-level older adults in subsidized public housing. Public Health Reports 1996;111:260-3.

13. Niefeld MR, Kasper JD. Access to ambulatory medical and long-term care services among elderly Medicare and Medicaid beneficiaries: organizational, financial, and geographic barriers. Medical Care Research and Review 2005;62:300-19.

14. Rask KJ, Williams MV, Parker RM, McNagny SE. Obstacles Predicting Lack of a Regular Provider and Delays in Seeking Care for Patients at an Urban Public Hospital. Journal of the American Medical Association 1994;271:1931-3.

15. Millman M. Access to health care in America: National Academies Press; 1993.

16. Haas P, Morse S, Becker S, Young L, Esling P. The influence of spatial and household characteristics on household transportation costs. Research in Transportation Business & Management 2013.

17. Current Lists of Metropolitan and Micropolitan Statistical Areas and Delineations. United States Census Bureau. (Accessed March 21, 2016, at http://www.census.gov/population/metro/data/metrodef.html.)

18. Zip Code Tabulation Areas. United States Census Bureau. (Accessed September 18, 2013, at http://www.census.gov/geo/reference/zctas.html.)

19. ZIP Code to ZCTA Crosswalk. American Academy of Family Physicians, 2015. at http://www.udsmapper.org/zcta-crosswalk.cfm.)

20. Rabe-Hesketh S, Skrondal A, Pickles A. Generalized multilevel structural equation modeling. Psychometrika 2004;69:167-90.

Table 3.1 Beneficiary demographic characteristics, health status, barriers to accessing health services, and mobility by mode of transportation to their usual source of care (USC) in the analytic sample from the Medicare Current Beneficiary Survey

	Mode of transportation to usual source of care			
	Drive	Being driven	Public transport/walk	Other
Total	**5,233**	**1,868**	**375**	**129**
Weighted percent	**71.7%**	**21.5%**	**5.2%**	**1.5%**
Male	48.5%	26.1%	38.2%	23.1%
Race/Ethnicity				
White	88.8%	76.9%	52.7%	65.9%
Black	7.2%	12.3%	25.8%	22.2%
Other	1.7%	2.6%	5.6%	0.5%
Asian	1.2%	3.3%	8.4%	3.0%
Hispanic	1.1%	4.9%	7.5%	8.5%
Age				
65-69	32.5%	13.7%	33.6%	14.8%
70-74	27.7%	16.5%	26.7%	17.0%
75-79	19.0%	18.5%	14.6%	18.4%
80-84	12.4%	21.2%	12.7%	18.3%
85+	8.4%	30.1%	12.3%	31.4%
Education				
Less than HS	12.5%	35.6%	35.2%	37.3%
HS Diploma/Vocational degree	32.4%	36.5%	27.9%	30.7%
Some college/Associates degree	24.2%	14.5%	13.8%	14.3%
Bachelor's degree or more	30.9%	13.4%	23.1%	17.6%
Trouble getting needed care	2.5%	4.5%	6.8%	4.8%
At least 1 Part B claim	63.5%	69.6%	62.4%	61.8%
At least 1 hospital stay	11.7%	26.5%	15.0%	26.0%
Dual eligible	5.3%	22.7%	34.0%	34.1%
Health Status				
Excellent	23.2%	7.8%	14.0%	12.0%
Very good	37.6%	21.2%	24.3%	21.3%
Good	27.6%	34.2%	34.1%	27.9%
Fair	9.6%	26.6%	21.9%	26.1%
Poor	2.1%	10.2%	5.7%	12.7%
Household composition				

Lives alone	27.7%	29.1%	42.2%	56.7%
1 other person	59.3%	45.5%	42.3%	30.8%
2+ other people	13.0%	25.4%	15.5%	12.5%
Completed survey in language other than English	1.6%	6.3%	14.5%	8.8%
Difficulty walking 1/4 mile or 2-3 blocks:				
No difficulty	66.3%	26.1%	58.9%	24.1%
little difficulty	10.9%	10.6%	10.8%	12.8%
some difficulty	8.3%	12.3%	10.7%	11.8%
A lot of difficulty	7.1%	15.9%	11.0%	14.5%
Unable to do	7.4%	35.0%	8.7%	36.9%
Location of USC				
Doctor's office/group practice	84.1%	85.4%	71.4%	75.9%
Doctor's clinic	11.1%	9.3%	13.3%	5.0%
Hospital outpatient department/ VA	3.6%	4.2%	11.1%	10.4%
Other	1.2%	1.2%	4.2%	8.7%

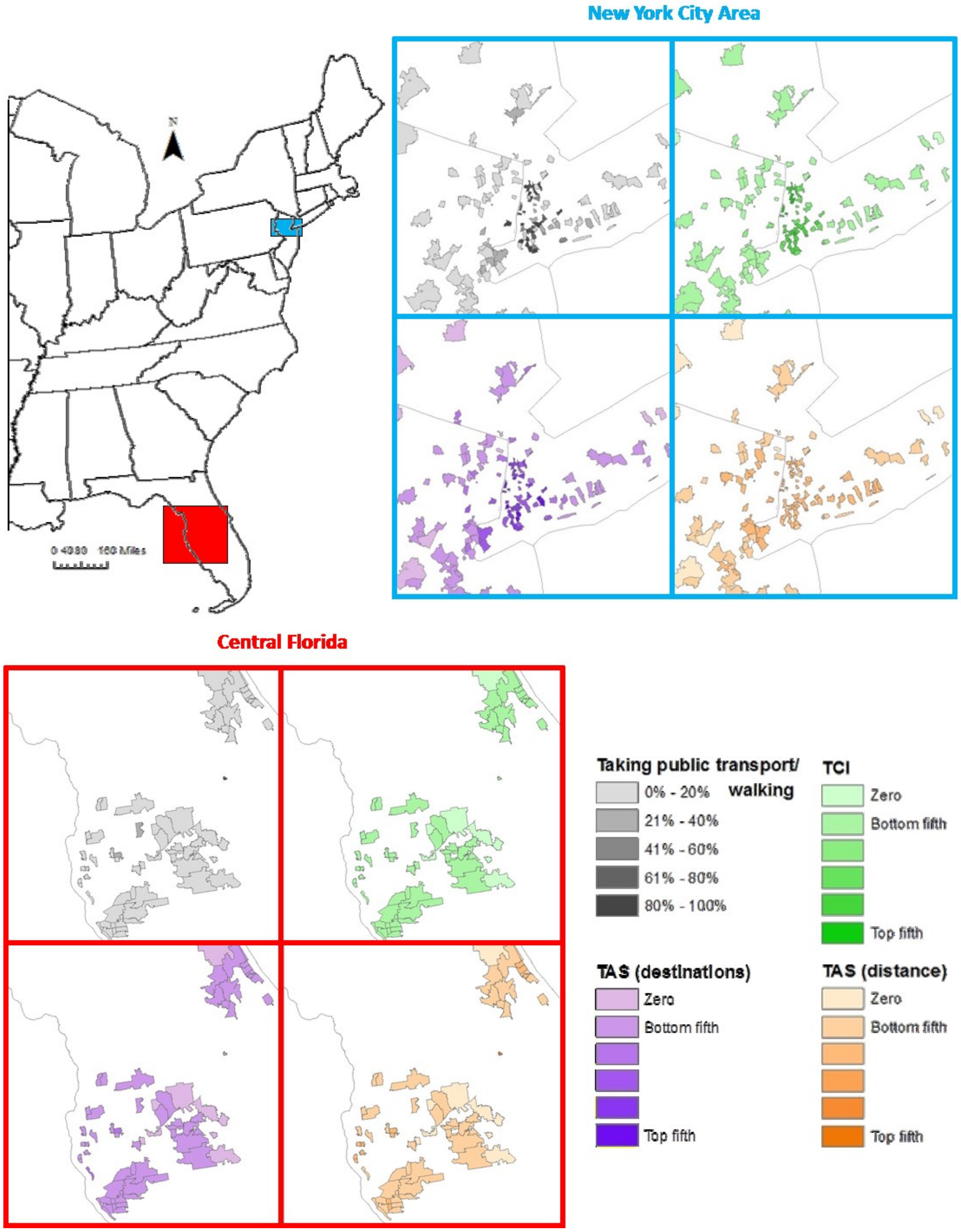
HS: High school
VA: Veteran’s administration facility

Table 3.2 Relationship between public transport accessibility measures and use of public transport/walking to usual source of care

	TCI			TAS (Distance)			TAS (Destinations)		
	ZCTAs	MCBS respondents		ZCTAs	MCBS respondents		ZCTAs	MCBS respondents	
		n	Public transport / walk to USC		n	Public transport / walk to USC		n	Public transport / walk to USC
Zero	199	1,099	1%	239	1,287	1%	239	1,287	1%
Bottom Fifth (worst accessibility)	1014	6,070	3%	640	4,160	3%	844	5,242	3%
Top Four-Fifths (best accessibility)	119	436	40%	453	2158	11%	249	1076	20%

TCI: Transit Connectivity Index
TAS: Transit Access Shed
ZCTA: ZIP Code Tabulation Area
MCBS: Medicare Current Beneficiary Survey
USC: Usual source of care

Figure 3.1 Public transit access and use of public transport/walking to get to a usual source of care in New York City and central Florida



Note: Missing areas are due to the sampling strategy of the Medicare Current Beneficiary Survey (MCBS)

TCI: Transit Connectivity Index
TAS: Transit Access Shed

Table 3.3 Model results for taking public transportation/walking compared to driving to get to a usual source of care

	Relative risk of taking public transportation	
	Base model	Final Model
TCI	1.07***	1.06***
TAS-distance	1.01	1.00
TAS-destinations	1.02***	1.02***
Female	1.70***	1.72***
Race/Ethnicity		
White	Ref	
Black	2.27***	2.20***
Other	2.98**	3.02**
Asian	4.54***	2.97**
Hispanic	3.40***	1.00
Age	1.02*	1.03**
Education		
Less than HS	3.18***	1.94**
HS Diploma/ Vocational degree	1.52*	1.25
Some college/Associates degree	1.22	1.05
Bachelor's degree or more	Ref	
Number of chronic conditions		1.11***
Hospitalization in the past year		1.28
Dual eligible		4.15***
Lives with others		0.68**
Completed survey in language other than English		3.12***
USC is not a doctors' office/clinic		2.39***
Fair/Poor health		1.92***
Some difficulty walking ¼ mile		0.69*

*p<0.05, **p<0.01, ***p<0.001

Table 3.4 Model results for taking public transportation/walking compared to driving to get to a usual source of care (USC) by public transportation access in stratified models

	Relative risk of taking public transit with more accessible public transportation		
	TCI	TAS-distance	TAS-destinations
Base model (demographics only)	1.07***	1.01	1.02***
USC is a doctor's office or clinic	1.08***	1.00	1.02**
Other type of USC facility	1.00	1.04*	1.04*
Lives alone	1.06**	1.01	1.02*
Lives with others	1.08***	1.01	1.02*
Completed survey in English	1.06***	1.01	1.02
Completed survey in other language	1.06	1.00	1.03*
Excellent/very good/good health	1.08***	1.01	1.01**
Fair/poor health	1.05**	1.00**	1.04***
No difficulty walking ¼ mile	1.05**	1.01	1.03***
Some difficulty walking ¼ mile	1.09***	1.01	1.01
Not dual eligible	1.07***	1.01	1.02**
Dual eligible	1.06*	1.10	1.03*

*p<0.05, **p<0.01, ***p<0.001

TCI: Transit Connectivity Index

TAS: Transit Access Shed

Note: Each row represents a separate model stratified by other barriers to care or health status. Models adjusted for demographics (age, race, gender, education, poverty level) and include city specific intercepts.

Chapter 4. Public Transport and Use of Health Services in Older Adults

Introduction

Older adults face multiple barriers to using health services, the second most commonly cited being transportation.[1,2] This barrier manifests in different ways for older adults than for the general population. As they age, older adults are less likely to be able to drive themselves,[3] they may have less robust social networks to provide transportation, and reduced mobility may force them to change previous transportation methods.[4] Additionally, older adults are likely to have multiple chronic conditions and need more frequent access to health services than younger individuals.[5]

As older adults are beginning to age in place, the number and proportion living in urban areas is expected to grow.[6] In such urban areas, public transportation can enable older adults' access to health services if it is available and if they choose to use it. Previously, we have found that older adults are more likely to use public transportation to get to their usual source of care if the transportation near their residence is higher quality. However, this does not necessarily mean that they are getting more appropriate care.

There is limited published research on public transportation with mixed findings; only some studies observed a relationship between public transport and access to health services. Among patients in an immigrant community who arrived at an outpatient clinic in suburban New York, 24% reported previously missing or rescheduling an appointment due to transportation problems. This proportion was even higher among the 15% of patients who had arrived at the clinic by bus.[7] In contrast, commuting time and use of public transportation in the area where women live were not associated with an individual's receipt of a pap smear or mammogram nationally.[8] Additionally, a study examining the effect of a bus driver strike on the proportion of missed appointments at a Minneapolis outpatient clinic found that the no-show rate was similar before and during the strike.[9]

We are not aware of any studies addressing the role of public transport in older adults' access to health services. Thus, this research begins to fill this gap by looking at patterns health service use via public transport across the United States and within large cities. We focus on whether public transport can enable more appropriate use of health services. In this study, we consider 2 types of health services that would indicate more appropriate care: primary care visits and potentially avoidable hospitalizations.

For primary care visits, we consider having at least one primary care visit during the year to be more appropriate than having no primary care visits. Less than half of older adults are up to date in terms of receiving core clinical preventive services,[10] which are typically provided by primary care providers (PCPs). Additionally, more than half of older adults have multiple chronic conditions,[5] and PCPs are able to help older adults manage their health across these conditions.

Avoidable hospitalizations, on the other hand, are an indicator of the lack of appropriate outpatient services. Generally, these are hospitalizations that could have been prevented if a patient were successfully managing a chronic condition with outpatient care.[11]

In this study, we evaluate the relationship between access to public transportation and appropriate use of health services for older adults. We ask whether individuals living in areas with better public transport are more likely to see a primary care physician in the last year and whether they are less likely to have an avoidable hospitalization.

Conceptual Framework

The role of public transport in appropriate use of health services fits into the health in all policy model, which focuses on the interaction between a patient's environment and their health, specifically including non-medical factors that influence health.[12] Within this context, transportation also plays a direct role in access to care, and is conceptualized within the Institute of Medicine's (IOM) model of access to care (Figure 4.1).[13] In this case, access is defined as "the timely use of personal health services to achieve the best possible health outcomes" (p4), which would encompass appropriate use of health services. The model includes three categories of barriers: structural, financial, and personal barriers to care; in which transportation is a structural barrier. According to the IOM's model, barriers to care influence use of services, which in turn influence outcomes including health status and equity of services. Mediating factors may influence the relationship between use of services and outcomes. Within the IOM's model, this study is focused on the first relationship between barriers to care (specifically transportation) and use of services.

Methods

Data

To understand the quality of public transportation at a beneficiary's residence, we used measures developed by the Center for Neighborhood Technology (CNT): the transit access shed (TAS) and the transit connectivity index (TCI). Both measures are based on 2010-2012 transit data and are available for all cities in the U.S. with at least 50,000 residents.[14]

Medicare beneficiary data comes from 2011 Medicare claims for a 5% random sample of fee-for-service (FFS) beneficiaries, restricted to those aged 65 and older living in an urban area. This source includes all FFS claims during the year, as well as demographic data (age, race, gender, zip code, urban status), and 27 chronic conditions identified by past service utilization.[15]

We added area level information about a beneficiary's residence based on their mailing address. This included median per capita income and proportion of households with vehicles from the US Census. We also used two indices that capture neighborhood depravation, the Area Deprivation Index (ADI) and the Townsend Index.

Measures

The independent variables of interest were measures of public transportation availability, the TCI and TAS. The TCI measures the number of transportation options and their frequency from a given location.). The TAS represents the area that can be reached via public transportation in 30 minutes including 2 indices: the maximum distance and the possible locations reached within that time period.[14] CNT has developed these measures at the Census block group level, but to match the Medicare claims, we aggregated these to the ZCTA level using the population weighted mean of the block groups. These two measures produce 3 indices (the TCI, TAS-distance, and TAS-destinations). Although each is based on measurable factors, all are scaled by the frequency of service and thus are not interpretable in specific units. The TCI is specifically scaled from 0-100, while the range of the TAS measures are larger. For all of these indices, greater values indicate better access to public transportation. Because both of the TAS measures have large raw values, we used TAS (destinations) divided by 10 and TAS (distance) divided by 1000 in our analyses. Additionally, beneficiaries' home locations were identified by zip code and converted to ZCTAs using a publicly available crosswalk.[16]

We identified primary care visits based on CMS' Primary Care Incentive Payment (PCIP) program. The PCIP was established under the Affordable Care Act and increases payments for primary care services provided by qualifying primary care providers beginning in 2011. CMS identifies primary care services provided in the outpatient setting with CPT codes 99201-99215. To be considered a primary care provider (PCP), at least 60% of a provider's Medicare claims must be for these primary care services.[17] For our analysis, we identified primary care visits as Medicare outpatient or carrier claims for primary care services provided by a qualifying PCP. We used a dichotomous measure of having no primary care visits in 2011 or having 1 or more visit.

We used the Agency for Healthcare Research and Quality's (AHRQ) prevention quality indicators (PQIs) to identify preventable hospitalizations. These are 14 indicators that can be used with hospital inpatient discharge data (such as the inpatient claims data) to identify hospitalizations for ambulatory care sensitive conditions based on ICD-9 codes.[11] The PQIs are typically used to evaluate hospitalization rates across a population using only inpatient claims data. In contrast, we have a defined population (5% of all FFS Medicare beneficiaries), and can identify all hospitalizations across this particular population. Thus, rather than evaluate the hospitalization rate for the entire population, we looked at the rate among the subpopulation with a particular ambulatory care sensitive condition. We identified beneficiaries with these conditions using Chronic Condition Warehouse (CCW) indicators. These are claims based indicators for each of 27 chronic conditions.[15]

In order to determine potentially preventable hospitalizations within the condition cohorts, we used only those PQIs that applied to a CCW chronic condition. This left us with 8 PQIs (diabetes short-term complication admissions, diabetes long-term complication admissions, uncontrolled diabetes admissions, lower-extremity amputation with diabetes, chronic obstructive pulmonary disease (COPD) admissions, hypertension admissions, congestive heart failure admissions, and angina admissions without procedure) across 5 condition cohorts (diabetes, COPD/asthma, hypertension, heart failure, and heart disease). Each condition cohort included all beneficiaries with the CCW flag prior to 2011. We then considered hospital admissions for the appropriate PQI for the cohort to be a potentially preventable admission. For each condition cohort, beneficiaries were dichotomized into having no potentially preventable admissions or one or more. Condition cohorts were not mutually exclusive, and beneficiaries with multiple chronic conditions could be in multiple disease cohorts.

We controlled for beneficiary demographics, health status, and home location. Demographics (sex, race/ethnicity, dual eligibility, and age) and health status (27 CCW chronic conditions and ESRD) were obtained from the Medicare Beneficiary Summary File. Characteristics of the beneficiary's home ZCTA were the proportion of households with vehicles, and median income from the Census. To account for other barriers to care that might interact with access to public transport, we included two indices that capture neighborhood depravation using Census variables in our analysis. One is the Area Depravation Index (ADI), developed in the United States based on predicting mortality at the county level.[18] The other is the Townsend Index, developed in the United Kingdom and more widely used outside the United States.[19]

Analysis

To evaluate whether beneficiaries living in areas with better public transportation are more likely to have a primary care visit during the year nationally, we used multilevel logit models for the odds of having at least one primary care visit as a function of public transport quality. In this case, we had three nested levels: individuals and two area levels. The beneficiary and their characteristics was the first individual level, the beneficiary's ZCTA and its characteristics was the second level, and the city where the ZCTA was located was the third level. We included both beneficiary and ZCTA measures as fixed effects by controlling for beneficiary demographics, health status, proportion of households with vehicles in the ZCTA, and ZCTA median income. City information was included only as random effects, with city specific intercepts based on the core based statistical area (CBSA) of a beneficiary's residence. These account for similarities within a city, such as use of the same public transport system. The CBSA maps counties into metropolitan and metropolitan areas.

To evaluate whether the quality of public transportation is associated with potentially preventable hospitalizations, we used similar models: multilevel logit models for an avoidable hospitalization as a function of public transport quality, controlling for beneficiary demographics and location of residence and including city-level random intercepts. We did not include health status covariates in these models as they are already disease cohorts and thus more homogenous than the entire sample. For this outcome, we evaluated the odds of having a potentially preventable admission for each condition cohort separately, but combined the 4 PQIs for diabetes into a single model.

Sensitivity Analysis

The main analysis included all older adults enrolled in FFS Medicare. Although we believe that the relationship between public transport and appropriate use of health services is likely to be similar across this population, there may be some variation by location and/or patient characteristics. For this reason, we conducted a number of sensitivity analyses to assess the consistency of our findings. For these sensitivity analyses, we looked at only two outcomes: having at least one primary care visit in the last year and heart failure hospital admissions among beneficiaries with chronic heart failure.

First, we assessed whether the relationship between access to public transport and primary care visits differed between cities. In this case, we modeled the relationship for 6 large cities with varying transportation systems: New York City, NY; Los Angeles, CA; Chicago, IL; Dallas, TX; Washington, DC; and Miami, FL, with a separate model for each city. These models controlled for the same beneficiary and ZCTA characteristics as the national model, with the exception of some of the CCW indicators. In the models for primary care, we collapsed all of the cancer CCW flags into a single cancer indicator to reduce the number of covariates for these smaller samples.

We also assessed whether the relationship differed for low income beneficiaries than the larger population. For these analyses, we restricted the sample in 2 ways. First, we looked only at dually eligible beneficiaries, and then we looked only at beneficiaries living in low income ZCTAs. In this case, low income ZCTAs were defined as those in the bottom 20% by median per capita income.

Results

Our full analysis sample included 1,068,958beneficiaries living in urban areas for which we had transportation quality measures. Beneficiary characteristics are shown in Table 4.1. Three quarters (77%) of these beneficiaries had at least one primary care visit in 2011. There were a total of 1,146,313 beneficiaries in at least one disease cohort. The disease cohorts ranged in size from 245,000 beneficiaries with a heart failure CCW flag to 800,000 beneficiaries with a hypertension CCW flag prior to 2011. The proportion of each cohort with a potentially preventable hospitalization also varied by diagnosis, with 3.5% of COPD/asthma patients hospitalized for one of those conditions, while only 0.06% of heart disease patients were hospitalized for angina without a procedure.

Table 4.2 shows the characteristics of the 21,236 ZCTAs that the beneficiaries resided in. The measures of transportation are highly variable. However, the majority of ZCTAs have low quality public transportation, with a few inner city areas having significantly better public transport.

The odds of having a primary care visit are shown in Table 4.3. Surprisingly, beneficiaries residing in ZCTAs with better public transportation are slightly less likely to visit a PCP, even after controlling for demographics, health status, and area measures. Despite the fact that the measures of public transport quality are statistically significant, the odds ratios are nearly equal to one hence yielding limited practical meaning for the relationship between access to public transport and having primary care visits.

The odds of a potentially preventable hospitalization for each disease cohort are shown in Table 4.4. In this case, there is no significant relationship between the quality of public transport and avoidable hospitalizations for any of the disease cohorts.

In these models, the relationships between the covariates and use of health services are what would be expected. For example, higher income beneficiaries are more likely to have appropriate use of health services, while dual eligible beneficiaries and those living in low income areas are less likely to use services appropriately.

The results from the sensitivity analyses are consistent with our findings for the overall sample. The odds of more appropriately using health services from the stratified city models are shown in Table 4.5. Across the six cities chosen, the same relationship holds as in the full sample: there is no meaningful relationship between living in areas with better public transport and having a PCP visit or potentially preventable hospitalization. Table 4.6 shows the sensitivity analysis evaluating the relationship between appropriate use of health services and access to public transport for low income beneficiaries. Again, the relationship for these low income populations does not differ from the overall sample.

Discussion

In this study we found that better access to public transport is not necessarily associated with more appropriate use of outpatient health services. The quality of public transport within a city was not associated with avoidable hospitalizations in our analysis. In terms of PCP visits, we found no meaningful relationship, although the models did have statistically significant inverse relationships: beneficiaries living in areas with better public transport may be less likely to have primary care visits. This relationship was consistent across cities and for the low income populations that we evaluated.

Previously, we have shown that when quality public transport is available, Medicare beneficiaries are more likely to take public transport to get to their usual source of care. It would follow that if public transport effectively removes transportation as a barrier to care, that areas with better public transport would have more appropriate use of outpatient services than areas with poor public transport. However, we have not found this to be the case, and there are a number of reasons that this may be.

One possibility is that other barriers to care may still prevent beneficiaries from using ambulatory care most appropriately. In this case, the improvement in access to care provided by public transport may be hidden by other barriers that are more significant and that we were not able to measure in this analysis. This could be financial barriers, which are more commonly cited than transportation, or health status, such as disability, that prevents individuals from using available public transport. It is also possible that public transportation does not effectively remove the barrier. Although it may allow patients to get to healthcare providers, it may be that public transportation is not a convenient method and is only used as a last resort to access care. This is particularly true with trip chaining; if an individual is traveling to other locations in addition to their health provider during the same trip, public transportation may not be a convenient way to access all of the locations. If this is the case, then even though public transportation does enable access to care, it still does not effectively remove the barrier.

Another possibility is that too few beneficiaries use public transportation for us to see the benefit in an analysis of the full Medicare population. Only around 4% of Medicare beneficiaries use public transportation to get to their usual source of care. Thus, even if the quality of public transportation is extremely important for these few beneficiaries, the much larger population that does not use public transport may make it difficult for us to see an association between the quality of public transport and health service use across the entire population. This would be consistent with previous research that has found public transport to be associated with health service use when they focus on a small area where individuals are likely to be dependent on public transport,[20] but not for the general population.[8,9] With the large sample size in this analysis, we were hoping to observe a relationship despite the fact that it had not been found in previous research.

Finally, it is possible that the transportation barrier is solved through other means. For example, state Medicaid programs are required to provide some sort of non-emergency medical transportation to their enrollees, which can include anything from public transportation vouchers to brokered transportation services.[21] Thus, depending on the transportation that their state provides dual eligible beneficiaries, transportation may not be a barrier to care. Other transportation solutions include social support programs,[22] community organizations that provide transportation[23] and shuttle services from healthcare providers. Or, it is possible that transportation is addressed along with other barriers to care, i.e. if an older adult needs someone to accompany them to an appointment, that person may also provide transportation to the provider.

There are some limitations of this analysis, particularly the measures that were available in the Medicare claims dataset. This dataset includes limited demographic and health status measures, which may have affected our ability to measure the independent association of public transport and health service use. There are few socioeconomic measures in our dataset: just race and dual eligibility. Other factors, such as more detailed poverty measures, availability of a car, or social support may influence a beneficiary's appropriate use of outpatient services. Thus, even though we did not find a different relationship for the low income populations we evaluated, there may still be differences that could be observed with a more granular measure of beneficiary socioeconomic status. Additionally, the health status measures are based on previous claims, and do not include measures of disability, which could be associated with use of public transport and outpatient service use. This analysis also includes only FFS beneficiaries, and in 2011 one quarter of all beneficiaries were not enrolled in FFS and instead enrolled in Medicare Advantage.[24] To the extent that those beneficiaries enrolled in Medicare Advantage have different access to public transportation or health service utilization than FFS beneficiaries, our findings are not generalizable to the broader Medicare population.

We only looked at health service utilization in a single year, and thus can only discuss the possible associations between access to public transportation and use of health services, rather than a causal relationship between the two measures. Additionally, there is a possibility that transportation availability and use are endogenous, particularly if beneficiaries or health providers choose to locate in areas that are accessible via public transport. If this were the case, then we would not be able to observe any effect of better public transportation because only those beneficiaries that needed public transportation would live in areas with better public transportation, while individuals with other means of transportation would choose to live in areas with poor public transit, and everyone would be able to access health services due to their location choices. Our evaluation of different cities tries to address this issue by comparing beneficiaries with access to the same transit system, but may not completely avoid it.

Another limitation is that the smallest geographic unit in the Medicare data is the zip code, although the transportation measures are available at the Census block group level. For older adults, the zip code may be too large of a unit to appropriately measure the quality of public transport, as they may not be willing or able to walk that far. Future research focusing on a more localized area may do a better job at determining areas with good and poor public transport within ZCTAs, and may in turn see a stronger relationship between public transport quality and appropriate use of health services. And policy solutions must be localized as well—policy interventions at the city level may only affect access in pockets of the entire service area.

Although we did not find a relationship between access to public transportation and more appropriate use of health services among the older adult Medicare population, it is possible that this is not the population for which public transportation is most important. Further research should evaluate whether access to public transportation enables more appropriate use of health services for other groups, particularly other vulnerable populations who may face transportation barriers to care.

Based on the finding that higher quality public transport is not associated with more appropriate use of outpatient services, further research may need to focus on how the barrier to transportation is being addressed and whether effective solutions can be expanded. A better understanding of Medicare and other transportation services could shed light on the effectiveness of other ways to address transportation as a barrier to care. These could include transportation options specifically for older adults or for all patients to specific providers. Further research should examine the current state of these options and how successful they are in enabling access to health services. If they are successful, the best policy option could be expanding these services rather than relying on public transportation for older adults to access health services.

References

1. Kullgren JT, McLaughlin CG, Mitra N, Armstrong K. Nonfinancial Barriers and Access to Care for U.S. Adults. Health Serv Res 2012;47:462-85.
2. Okoro CA, Strine TW, Young SL, Balluz LS, Mokdad AH. Access to health care among older adults and receipt of preventive services. Results from the Behavioral Risk Factor Surveillance System, 2002. Preventive Medicine 2005;40:337-43.
3. Flaherty JH, Stalvey B, Rubenstein L. A consensus statement on nonemergent medical transportation services for older persons. Journals of Gerontology Series A-Biological Sciences and Medical Sciences 2003;58:826-31.
4. Rittner B, Kirk AB. Health-Care and Public Transportation Use by Poor and Frail Elderly People. Soc Work 1995;40:365-73.
5. Anderson G, Horvath J. The growing burden of chronic disease in America. Public health reports 2004;119:263.
6. DeGood K. Aging in Place, Stuck without Options: Fixing the Mobility Crisis Threatening the Baby Boom Generation: Transportation for America; 2011.
7. Silver D, Blustein J, Weitzman BC. Transportation to Clinic: Findings from a Pilot Clinic-Based Survey of Low-Income Suburbanites. Journal of Immigrant and Minority Health 2012;14:350-5.
8. Coughlin SS, King J. Breast and cervical cancer screening among women in metropolitan areas of the United States by county-level commuting time to work and use of public transportation, 2004 and 2006. BMC Public Health 2010;10.

9. Pheley AM. Mass transit strike effects on access to medical care. Journal of Health Care for the Poor and Underserved 1999;10:389-96.

10. Benson W, Aldrich N. CDC Focuses on Need for Older Adults to Receive Clinical Preventive Services: Centers for Disease Control and Prevention; 2012.

11. Guide to prevention quality indicators: hospital admission for ambulatory care sensitive conditions: Agency for Healthcare Research and Quality; 2001.

12. Linda Rudolph JC, Karen Ben-Moshe, Lianne Dillon. Health in All Policies: A Guide for State and Local Governments. Washington, DC and Oakland, CA: American Public Health Association and Public Health Institute; 2013.

13. Millman M. Access to health care in America: National Academies Press; 1993.

14. Haas P, Morse S, Becker S, Young L, Esling P. The influence of spatial and household characteristics on household transportation costs. Research in Transportation Business & Management 2013.

15. Chronic Condition Data Warehouse Medicare Administrative Data User Guide. Buccaneer Computer Systems and Service, Inc., 2013. (Accessed August 18, 2013, at https://www.ccwdata.org/cs/groups/public/documents/document/ccw_userguide.pdf.)

16. ZIP Code to ZCTA Crosswalk. American Academy of Family Physicians, 2015. at http://www.udsmapper.org/zcta-crosswalk.cfm.)

17. Centers for Medicare and Medicaid Services. Summary Information Regarding Medicare's Primary Care Incentive Payment Program (PCIP) April 30, 2014.

18. Singh GK. Area deprivation and widening inequalities in US mortality, 1969-1998. American Journal of Public Health 2003;93:1137-43.

19. Galobardes B, Lynch J, Smith GD. Measuring socioeconomic position in health research. British Medical Bulletin 2007;81-82:21-37.

20. Arcury TA, Preisser JS, Gesler WM, Powers JM. Access to transportation and health care utilization in a rural region. Journal of Rural Health 2005;21:31-8.

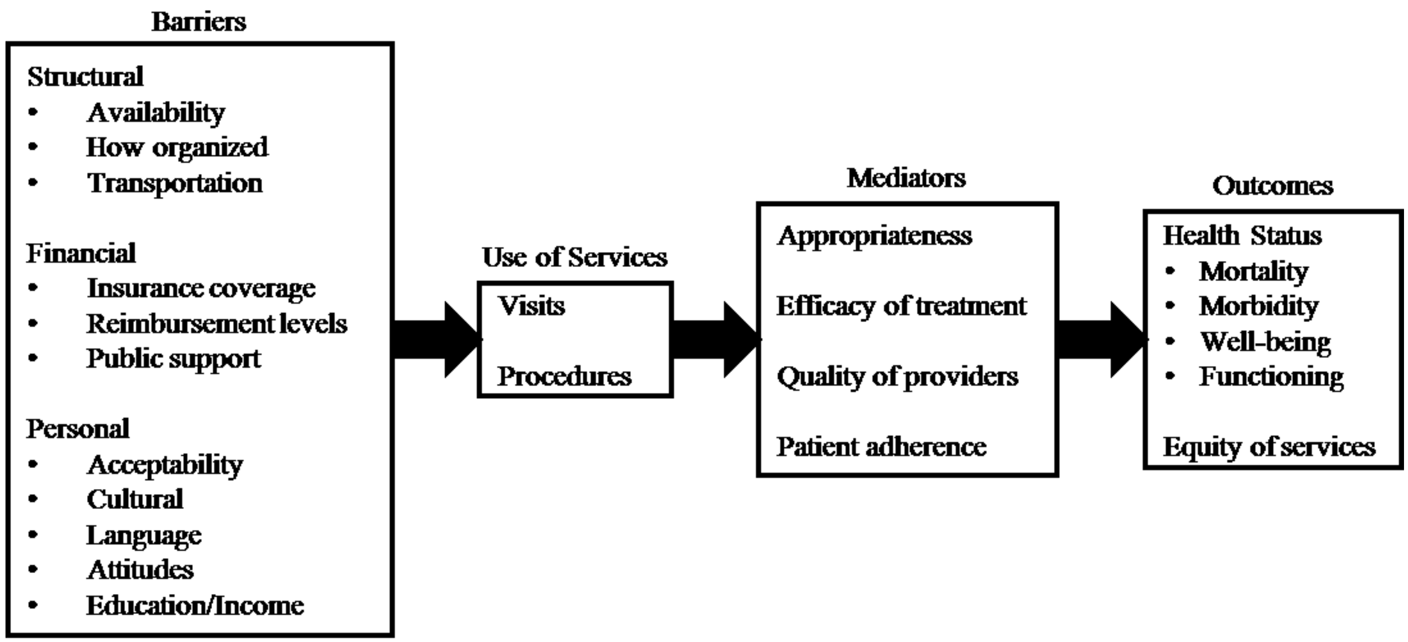
21. Non-Emergency Medical Transportation: A Vital Lifeline for a Healthy Community. National Conference of State Legislatures, 2015. (Accessed March 11, 2016, at http://www.ncsl.org/research/transportation/non-emergency-medical-transportation-a-vital-lifeline-for-a-healthy-community.aspx.)

22. Shier G, Ginsburg M, Howell J, Volland P, Golden R. Strong Social Support Services, Such As Transportation And Help For Caregivers, Can Lead To Lower Health Care Use And Costs. Health Affairs 2013;32:544-51.

23. Guengerich T. Neighbors Helping Neighbors: Qualitative Study of Villages Operating in the District of Columbia: AARP; 2009.

24. Kaiser Family Foundation. Medicare Advantage Fact Sheet June 2015.

Figure 4.1 Institute of Medicine's model of access to personal health care services



Source: Millman M. Access to health care in America: National Academies Press; 1993. Page 35.

Table 4.1 Beneficiary outcomes, demographics, and chronic conditions in 2011 for 5% Medicare fee-for-service analysis sample and disease cohorts

		Disease Cohorts				
	All beneficiaries	COPD or Asthma	Heart Failure	Hypertension	Heart Disease	Diabetes
Beneficiaries	1,068,958	275,482	245,678	803,036	477,936	345,399
Primary care visits in 2011						
At least 1	77.2%					
Mean	4.1					
Avoidable hospitalization		2.67%	3.46%	0.19%	0.06%	0.89%
Mean age	76.1	78.3	80.3	77.5	78.7	77.1
Female	57.6%	59.8%	58.0%	58.7%	53.3%	55.4%
Race						
White	85.9%	86.4%	83.7%	85.1%	86.1%	80.4%
Black	8.2%	8.0%	10.4%	9.1%	8.1%	11.7%
Asian	2.0%	1.9%	2.0%	2.0%	2.0%	2.7%
Hispanic	1.8%	2.1%	2.4%	1.8%	2.0%	2.7%
Other	2.1%	1.6%	1.7%	1.9%	1.8%	2.5%
Dual eligible	13.0%	19.6%	21.3%	14.6%	16.2%	19.5%
Chronic conditions						
AMI	0.8%	7.1%	11.4%	5.2%	9.0%	6.4%
Alzheimer's Disease	5.4%	8.1%	10.6%	6.4%	7.9%	7.1%
Alzheimer's Disease, Related Disorders,	11.4%	18.3%	23.5%	14.1%	17.4%	15.9%

	All beneficiaries	**Disease Cohorts** COPD or Asthma	Heart Failure	Hypertension	Heart Disease	Diabetes
or Senile Dementia						
Atrial Fibrillation	9.2%	20.8%	33.3%	15.9%	22.6%	17.3%
Cataract	22.6%	73.3%	76.2%	68.4%	73.0%	68.0%
Chronic Kidney Disease	15.0%	28.8%	39.2%	22.7%	28.2%	30.5%
COPD	11.1%	84.1%	44.2%	26.0%	33.6%	29.5%
Heart Failure	15.5%	43.5%	100.0%	29.4%	42.4%	37.4%
Diabetes	28.0%	43.1%	52.6%	40.3%	45.3%	100.0%
Glaucoma	12.1%	25.5%	27.5%	24.3%	25.9%	26.6%
Hip / Pelvic Fracture	0.9%	5.3%	6.5%	3.8%	4.6%	3.7%
Heart Disease	32.5%	66.3%	82.6%	55.0%	100.0%	62.7%
Depression	12.2%	36.4%	36.8%	26.9%	30.8%	29.5%
Osteoporosis	8.2%	28.6%	28.3%	23.2%	25.1%	20.9%
Arthritis	31.3%	64.8%	67.8%	56.2%	62.0%	58.2%
Stroke	4.1%	20.9%	26.3%	16.4%	21.2%	18.8%
Breast Cancer	3.4%	6.1%	6.1%	5.7%	5.5%	5.4%
Colorectal Cancer	1.4%	3.8%	4.3%	3.2%	3.7%	3.5%
Prostate Cancer	3.9%	6.4%	7.1%	6.3%	7.5%	6.6%
Lung Cancer	0.9%	3.0%	1.8%	1.3%	1.6%	1.3%
Endometrial Cancer	0.3%	0.9%	1.1%	0.9%	0.9%	0.9%
Anemia	24.9%	65.5%	75.4%	55.5%	64.8%	62.7%
Asthma	4.4%	40.9%	19.8%	12.6%	15.2%	14.7%
Hyperlipidemia	50.9%	83.1%	87.8%	83.6%	89.0%	89.6%

		Disease Cohorts				
	All beneficiaries	COPD or Asthma	Heart Failure	Hypertension	Heart Disease	Diabetes
Benign Prostatic Hyperplasia	7.2%	21.0%	23.0%	19.2%	23.4%	20.7%
Hypertension	61.5%	89.4%	96.2%	100.0%	92.4%	93.7%
Hypothyroidism	9.8%	24.9%	27.3%	21.0%	23.4%	22.4%
ESRD	0.6%	1.1%	2.0%	0.8%	1.1%	1.5%

Note: Disease cohorts are based on the presence of the chronic condition prior to 2011 using claims
COPD: Chronic obstructive pulmonary disease
AMI: Acute myocardial infarction
ESRD: End stage renal disease

Table 4.2 Public transit availability, household characteristics, and deprivation measures for Zip Code Tabulation Areas (ZCTAs) in 2011 for 5% Medicare fee-for-service analysis sample and disease cohorts

		Disease Cohorts				
	All beneficiaries	COPD or Asthma	Heart Failure	Hypertension	Heart Disease	Diabetes
ZCTAs	21,236	18,965	18,505	20,849	19,967	19,331
TCI	1.8	2.0	2.0	1.8	1.9	1.9
(Standard Deviation)	(5.7)	(5.9)	(5.9)	(5.7)	(5.8)	(5.8)
TAS: Distance (SD)	6	7	7	6	6	6
	(11.3)	(11.6)	(11.6)	(11.3)	(11.5)	(11.5)
TAS: Destinations (SD)	7.0	7.6	7.8	7.1	7.4	7.5
	(14.7)	(15.2)	(15.3)	(14.8)	(15.0)	(15.2)
Households with						
No vehicles	7%	7%	7%	7%	7%	7%
1 vehicle	30%	31%	31%	30%	31%	31%
2 vehicles	39%	39%	39%	39%	39%	39%
3+ vehicles	24%	23%	23%	24%	24%	24%
Median income	$28,329	$27,779	$27,829	$27,587	$27,690	$27,777
Townsend index (SD)	-0.03	-0.02	-0.02	-0.03	-0.03	-0.03
	(1.5)	(1.3)	(1.4)	(1.5)	(1.4)	(1.4)
Area Depravation Index (SD)	100.2	94.7	94.5	95.4	95.0	94.8
	(16.3)	(22.5)	(22.5)	(22.2)	(22.4)	(22.4)

TCI: Transit Connectivity Index
TAS: Transit Access Shed

Table 4.3 Model results for having at least one primary care visit during the year compared to no visits

Variable	Odds Ratio for having at least 1 primary care visit
Transportation Measures	
TCI	**1.000**
TAS (distance)	**0.998*** **
TAS (destinations)	**0.996*** **
Female	1.485***
Race/Ethnicity	
White	Ref
Black	0.769***
Asian	1.154***
Hispanic	0.899***
Other	0.886***
Dual eligible	0.636***
Age	0.995***
Townsend Index	1.002
ADI	1.001***
Households with	
No vehicles	1.004***
1 vehicle	1.002***
2 vehicles	1.005***
3+ vehicles	Ref
ZCTA Median income	1.000***
Comorbidities	
AMI	0.765***
Alzheimer's Disease	0.659***
Alzheimer's Disease, Related Disorders, or Senile Dementia	0.535***
Atrial Fibrillation	1.359***
Cataract	1.517***
Chronic Kidney Disease	1.005
COPD	1.170***
Heart Failure	0.693***
Diabetes	1.309***
Glaucoma	1.493***
Hip / Pelvic Fracture	0.665***

Variable	Odds Ratio for having at least 1 primary care visit
Heart Disease	0.962***
Depression	1.032***
Osteoporosis	1.331***
Arthritis	1.677***
Stroke	0.797***
Breast Cancer	1.825***
Colorectal Cancer	1.362***
Prostate Cancer	2.018***
Lung Cancer	1.786***
Endometrial Cancer	1.838***
Anemia	1.076***
Asthma	1.501***
Hyperlipidemia	2.597***
Benign Prostatic Hyperplasia	1.794***
Hypertension	2.957***
Hypothyroidism	1.291***
ESRD	0.698***

*p<0.05, **p<0.01, ***p<0.001

Note: Model includes city specific intercepts

TCI: Transit Connectivity Index
TAS: Transit Access Shed
ADI: Area deprivation index
ZCTA: Zip Code Tabulation Area
COPD: Chronic obstructive pulmonary disease
AMI: Acute myocardial infarction
ESRD: End stage renal disease

Table 4.4 Model results for having a potentially preventable hospitalization during the year compared to none by disease cohorts

	Odds ratio for having a potentially preventable hospitalization				
	PQI #5 (COPD/Asthma)	PQI #8 (Heart Failure)	PQI #7 (Hypertension)	PQI #13 (Heart Disease)	PQIs #1, 3, 14, 16 (Diabetes)
Transport Measures					
TCI	0.998	0.999	1.009	0.983	0.997
TAS (distance)	1.000	1.001	0.994	1.003	1.002
TAS (destinations)	1.000	0.999	1.001	0.986	0.999
Female	1.071*	0.830***	1.880***	1.057	0.758***
Race/Ethnicity					
White	Ref				
Black	0.997	1.225***	2.550***	1.058	1.815***
Asian	0.534***	0.650***	0.933	0.610	0.658**
Hispanic	0.723***	0.880	1.747***	0.878	1.178
Other	0.807	1.002	1.122	1.035	0.952
Dual eligible	1.673***	1.213***	1.584***	1.772***	1.875***
Age	0.987***	1.018***	1.030***	0.997	0.991**
Townsend Index	1.041**	1.019	1.020	1.093	1.029
ADI	1.002	1.003**	1.001	0.993	1.001
Households with:					
No vehicles	1.002	0.998	1.001	1.010	1.009
1 vehicle	0.995*	0.999	1.001	0.988	0.998
2 vehicles	0.998	1.001	1.001	0.972	1.003

3+ vehicles	Ref				
ZCTA Median income	1.000**	1.000	1.000	1.000*	1.000

*p<0.05, **p<0.01, ***p<0.001

Notes: Model includes city specific intercepts
Disease cohorts are based on the presence of the chronic condition prior to 2011 using claims

PQI #1: Diabetes Short-Term Complications Admission
PQI #3: Diabetes Long-Term Complications Admission
PQI #5: Chronic Obstructive Pulmonary Disease (COPD) or Asthma Admission
PQI #7: Hypertension Admission
PQI #8: Heart Failure Admission
PQI #13: Angina without Procedure Admission
PQI #14: Uncontrolled Diabetes Admission
PQI #16: Lower-Extremity Amputation with Diabetes

TCI: Transit Connectivity Index
TAS: Transit Access Shed
ADI: Area deprivation index
ZCTA: Zip Code Tabulation Area
COPD: Chronic obstructive pulmonary disease
AMI: Acute myocardial infarction
ESRD: End stage renal disease

Table 4.5 Model results for having a primary care visit or a potentially preventable heart failure admission by city

	Odds ratio					
	Washington, DC	New York City	Los Angeles	Chicago	Dallas	Miami
Primary care visit						
TCI	1.000	0.999	0.990*	1.005	0.995	0.989
TAS (distance)	0.985***	0.992***	0.999	0.998	1.004	0.993*
TAS (destinations)	0.999	0.995***	1.003	0.995**	0.998	0.986***
PQI #8 (Heart failure admission)						
TCI	1.009	1.007	0.967	1.001	0.964	0.975
TAS (distance)	0.986	1.004	1.011	0.983*	0.956	1.024
TAS (destinations)	0.997	0.994	1.004	1.000	1.035	0.996

*p<0.05, **p<0.01, ***p<0.001

Notes: Models control for beneficiary demographics and chronic conditions as well as area measures for the beneficiary's residence

Heart failure admissions are among beneficiaries with heart failure prior to 2011 using claims

TCI: Transit Connectivity Index

TAS: Transit Access Shed

Table 4.6 Model results for having a primary care visit or odds of a potentially preventable heart failure admission by city for low income beneficiaries

	Odds ratio	
	Dual Eligible	Low income ZCTA (bottom 20% of median PCI)
Primary care visit		
TCI	1.005*	1.001
TAS (distance)	0.994***	0.995***
TAS (destinations)	0.998	0.999
PQI #8 (Heart failure admission)		
TCI	0.997	1.000
TAS (distance)	1.001	0.999
TAS (destinations)	0.998	0.998

*p<0.05, **p<0.01, ***p<0.001

Notes: Models control for beneficiary demographics and chronic conditions as well as area measures for the beneficiary's residence

Heart failure admissions are among beneficiaries with heart failure prior to 2011 using claims

TCI: Transit Connectivity Index

TAS: Transit Access Shed

Chapter 5. Conclusions

This research has explored the relationship between access to public transportation and access to health services for older adults in a number of ways. First, I validated two measures of public transportation accessibility, the TAS and the TCI. Second, I evaluated whether older adults with better access to public transportation are more likely to use public transport it to get to their usual source of care. Finally, I looked at whether access to public transportation facilitates more appropriate use of outpatient health services. Overall, I find that these are valid measures of public transport accessibility, and that better public transportation is associated with use of public transportation but not with more appropriate use of outpatient services.

This adds to the overall understanding of barriers to care among the older adult population in the United States. Transportation is a frequently cited barrier to care, however, this research does not find that public transportation effectively removes the barrier. This is in contrast to the fact that older adult Medicare beneficiaries living in areas with better public transport are more likely to take it to get to their usual source of care. Perhaps, public transportation is an option of last resort, but the transportation barrier is generally addressed another way. It is possible that beneficiaries still have difficulty getting needed care on a regular basis, but also possible that older adults are chaining trips across a number of locations, making it difficult to use public transportation to accomplish all of these tasks, or that they are addressing multiple barriers by having someone else drive and accompany them to appointments.

I also only assessed outpatient service utilization as measured by use of primary care services and avoidable hospitalizations based on Medicare claims. I do not know whether public transportation plays a different role for accessing different types of health services, such as follow-up testing or prescriptions. Future research could assess what role public transportation plays in access to non-physician services, possibly using the same public transportation measures but focusing on other services available in the claims data or services only available in electronic health records.

To better understand how older adults get to outpatient services, further research is needed. First, it is necessary to know what transportation options are available to older adults. Most older adults drive themselves to their usual source of care, while the next most common option is being driven. However, as they age in place, driving themselves becomes more difficult. Further research should focus on how older adults who do not use private vehicles (either by driving themselves or by being driven) get to healthcare providers, and the factors that influence their decision to take particular mode of transport. This could include additional analyses focused on the Medicare beneficiaries who actually take public transportation. In addition, other surveys might provide a more nuanced view than the information used here from the MCBS. For example, the National Health and Aging Trends Survey (NHATS) allows respondents to select more than one mode of transportation rather than a single mode in the MCBS.[1]

For those that are not able to have someone else drive them, public transportation is only one of the available options. I know of some existing solutions to fill the gap in transporting individuals to their health providers. These include community organizations, senior citizen vans, and shuttles operated by providers. Despite all of these options, transportation remains a barrier to care. Additional qualitative research could provide a more nuanced understanding of how older adult beneficiaries perceive and address transportation barriers to accessing health services.

Limitations of each analysis are included in their respective chapters, but some limitations common to all analyses are worth mentioning here. First, the analyses rely on the TAS and TCI as valid measures of public transit accessibility at a given origin point. Although I have shown these to indeed be valid measures, public transportation accessibility is only one aspect of a beneficiary's decision to use public transit. Transit accessibility of the destination, other factors that influence transit quality, beneficiary mobility, access to a private vehicle, and other built environment characteristics are just some of the other factors that go into the decision of what mode of transit to use. Second, all analyses, but particularly secondary analyses like these, have factors that they are unable to measure. In my analyses, the inability to account for social support and caregiving at home make it difficult to identify beneficiaries who are most in need of alternative transportation. In the analyses of health service utilization, I was even more limited in my ability to measure functional status and health status. Finally, I assessed access to public transportation from a beneficiary's home, although that may not always be the origin for a healthcare trip.

The population of interest for this research is older adult Medicare beneficiaries. Thus, my findings may not be generalizable to other populations. In particular, other vulnerable populations such as low income individuals or Medicaid beneficiaries may use public transportation differently than older adults. If such differences exist, they may affect the role of transportation in accessing health services for these populations. Future research could focus on the role of public transportation for other populations including Medicaid beneficiaries, children, or low income adults.

Despite these limitations, this adds to the body of access to care literature by exploring the role of public transportation more thoroughly. These findings lead to a number of policy implications. First, there is a valid measure of access to public transportation that has already been developed and is available for most cities in the United States. Future research and planning can include these measures to better understand the built environment and assess changes to the public transport system. Given that individuals with better access to public transport are more likely to take it to get to their usual source of care, improving the public transportation system may facilitate access to care for these individuals. This can be as simple as adding stops to existing bus lines that would increase public transport accessibility and in turn may increase use. This is particularly important for beneficiaries who do not have access to private vehicle and have difficulty finding someone to drive them. Finally, older adults who do face transportation barriers to care may need options besides the public transport system to get the health services they need.

References

1. National Health and Aging Trends Suvey. 2015. (Accessed March 31, 2016, at http://www.nhats.org/scripts/default.htm.)

Curriculum Vitae

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Zuckerman RB, Sheingold SH, Orav EJ, Ruhter J, Epstein AE. Readmissions, Observation, and the Hospital Readmissions Reduction Program. *New England Journal of Medicine.* 2016; February 24.

Sheingold, SH, **Zuckerman R**, Sharzer A. Understanding Medicare Hospital Readmission Rates and Differing Penalties between Safety-Net and Other Hospitals. *Health Affairs*. 2016: 35(1):124-131.

Zuckerman RB, Stearns SC, Sheingold SH. Hospice Use, Hospitalization, and Medicare Spending at the End of Life. *Journals of Gerontology Series B: Social Sciences*; 2015: December 11.

Stearns SC, Sheingold S, **Zuckerman RB**. Explaining Variation in Hospice Visit Intensity for Routine Home Care. *Medical care*. 2014; 52(1):56-62.

Zuckerman R, Tinsley L, Hawk H, Cohen B. Perceived Reactions to Race and Health Status in the Massachusetts Behavioral Risk Factor Surveillance System Survey. *Ethnicity & Disease.* 2012; 22(4):492-496.

Milne CP, **Zuckerman R**. Biopharma Perspectives on the Business Prospects for Personalized Medicines. *Personalized Medicine*. 2011; 8(5):541-550.

Lamberti M, **Zuckerman R**, Howe D, Shapiro L, Getz K. Factors influencing investigative site willingness and ability to participate in clinical trials. *Drug Information Journal*. 2011; 45(3):377-390.

Getz K, **Zuckerman R**, Cropp A, Hindle A, Krauss R, Kaitin K. Measuring the incidence, causes and repercussions of protocol amendments. *Drug Information Journal*. 2011; 45(3):265-275.

Zuckerman R, Getz K, Kaitin K. A new mechanism for tracking publicly available study volunteer demographics. *Drug Information Journal*. 2011; 45(1):55-64.

Getz K, **Zuckerman R**, DiMasi J, Kaitin K. Drug development portfolio and spending practices after mergers and acquisitions. *Drug Information Journal*. 2009; 43(4).

Harris J, Luke D, **Zuckerman R**, Shelton S. Forty years of secondhand smoke research: Examining the gap between discovery and delivery. *American Journal of Preventive Medicine*. 2009; 36(6):538-548.